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1 Airport location and characterization

1.1 Location

The main influence on the airport location is the presence of other airports in the area. Since Jakarta has already one airport, the 18th worldwide, the location has to be selected carefully. Other factors that influenced the airports final location were the ease to provide the airport with good connections to the city and a wide area available in order to increase the airports infrastructure if needed in the future. After considering all those factors, the location decided can be defined by the following coordinates:

- Latitude: 6°08'21"

- Longitude: 107°06'40"

- Altitude: 30meters approximately.

Since the area chosen is extremely marshy, the excavations to deeper levels are going to be avoided as much as possible due to its difficulties and cost. However, that type of terrain gives us some advantage due to its flatness.

1.2 Meteorology

1.2.1 Temperature

The reference temperature of airports is important to be calculated as soon as possible since it has an effect on the performance of the airplanes during the phases of landing and takeoff.

In order to calculate this temperature, the definition given by the ICAO will be used. ICAO states that: "The aerodrome reference temperature shall be the monthly mean of the daily maximum temperatures for the hottest month of the year (the hottest month being that which has the highest monthly mean temperature). This temperature shall be averaged over a period of years".

Taking into account the hypothesis that the temperatures obtained on Soekarno-Hatta Airport can also be used in order to calculate our reference temperature due to the fact that both airports are only separated by a distance of 60km, a comparison study has been made.

The final reference temperature obtained is $T_{ref} = 32,38°C$.

The temperature values and study is further detailed in the attachments.

1.2.2 Wind

In order to calculate the influence of the winds the first thing done is the graph of the winds intensity and their direction. This graph is commonly called wind rose graph. The graph obtained making use of Microsoft Excel software is:

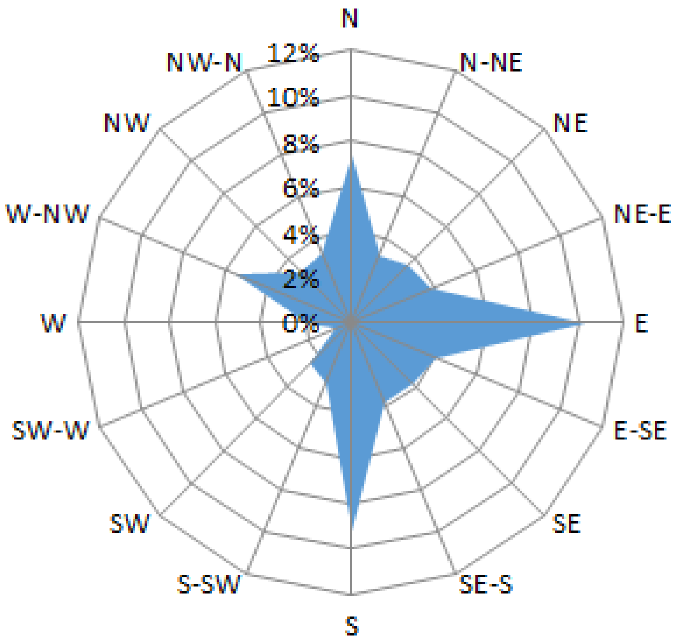

Figure 1.2.1: Wind Rose Graph

Once this step is done, the next thing to do is to calculate the coefficient of use by a diagram of frequencies. Following the recommendations given by the ICAO on the attachment 14, the maximum value that the transversal component can achieve is 37km/h or 20knots for a runway of >1500m.

The diagram of frequencies basically creates a rectangular area that depends on the runway axis, the width of the runway and the maximum transversal component.

After calculating the coefficient of use by all the directions, the graph obtained is the following:

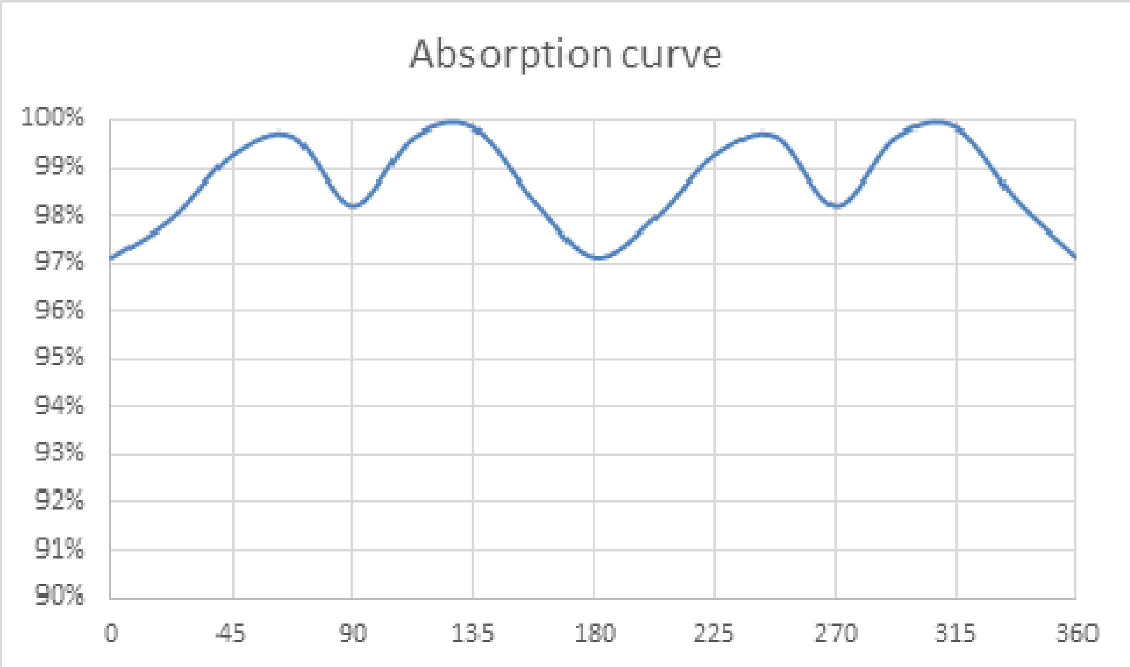

Figure 1.2.2: Coefficient of use depending on the orientation

As it can be see, the coefficient is higher than 95% in any direction. According to that, the final orientation chosen is SE-NW.

2 Runway design

2.1 Introduction

The runway is a key piece of the airport and the air side design due to the fact that defines the maximum dimensions of the operative air planes. Its function is to successfully guarantee the landing and takeoff operation.

In order to successfully define the runway, the instructions and requirements given in the Annex 14 given by the ICAO have been followed.

2.2 Runway's Length

The reference field length is defined as the minimum distance needed in order to perform a takeoff operation with the maximum homologated takeoff weight using sea level conditions, without wind and considering 0° slope.

In order to calculate the runway length, the first step is to choose the most restrictive air plane that is going to operate on that runway. Afterwards, that length has to be corrected by the runway slope, the altitude of the airport and the mean temperature.

Due to the fact that the airport has two runways, from now on, the runway used for international flights will be referred as runway 1 and the one used for domestic flights will be named runway 2.

2.2.1 Runway 1

The biggest airplanes that will operate on this runway are the Boeing 777-300ER and the Airbus A330-300.

2.2.1.1 Reference Field Length

Starting with the B777-300ER, using the ACAP (Aircraft Characteristic for Airport Planning), the values of the MTOW (Maximum TakeOff Weight) and MLW (Maximum Landing Weight) can be obtained.

2.1.1 General Characteristics: Model 777-200LR. -300ER, 777F

CHARACTERISTICS	UNITS	777-200LR	777-300ER	777-F
MAX DESIGN TAXI WEIGHT	POUNDS	768,000	777,000	768,800
	KILOGRAMS	348,358	352,442	348,722
MAX DESIGN TAKEOFF WEIGHT	POUNDS	766,000	775,000	766,800
	KILOGRAMS	347,452	351,535	347,815
MAX DESIGN LANDING WEIGHT	POUNDS	492,000	554,000	575,000
	KILOGRAMS	223,168	251,290	260,816
MAX DESIGN ZERO FUEL WEIGHT	POUNDS	461,000	524,000	547,000
	KILOGRAMS	209,106	237,683	248,115
OPERATING EMPTY WEIGHT (1)	POUNDS	320,000	370,000	318,300
	KILOGRAMS	145,150	167,829	144,379
MAX STRUCTURAL PAYLOAD	POUNDS	141,000	154,000	228,700
	KILOGRAMS	63,957	69,853	103,737
TYPICAL SEATING CAPACITY	TWO CLASS	279 (4)	339 (6)	N/A
	THREE CLASS	301 (5)	370 (7)	N/A
MAX CARGO --LOWER DECK	CUBIC FEET	5,656 (2)	7,552 (2)	22,371 (3)
	CUBIC METERS	160.2 (2)	213.8 (2)	633.5 (3)
USABLE FUEL	U.S. GALLONS	47,890	47,890	47,890
	LITERS	181,283	181,283	181,283
	POUNDS	320,863	320,863	320,863
	KILOGRAMS	145,538	145,538	145,538

Figure 2.2.1: Maximum weights of the B777 depending on its configuration.

The next step is to calculate using the following graph the takeoff distance required with standard day + 15ºC = 30ºC and sea level conditions.

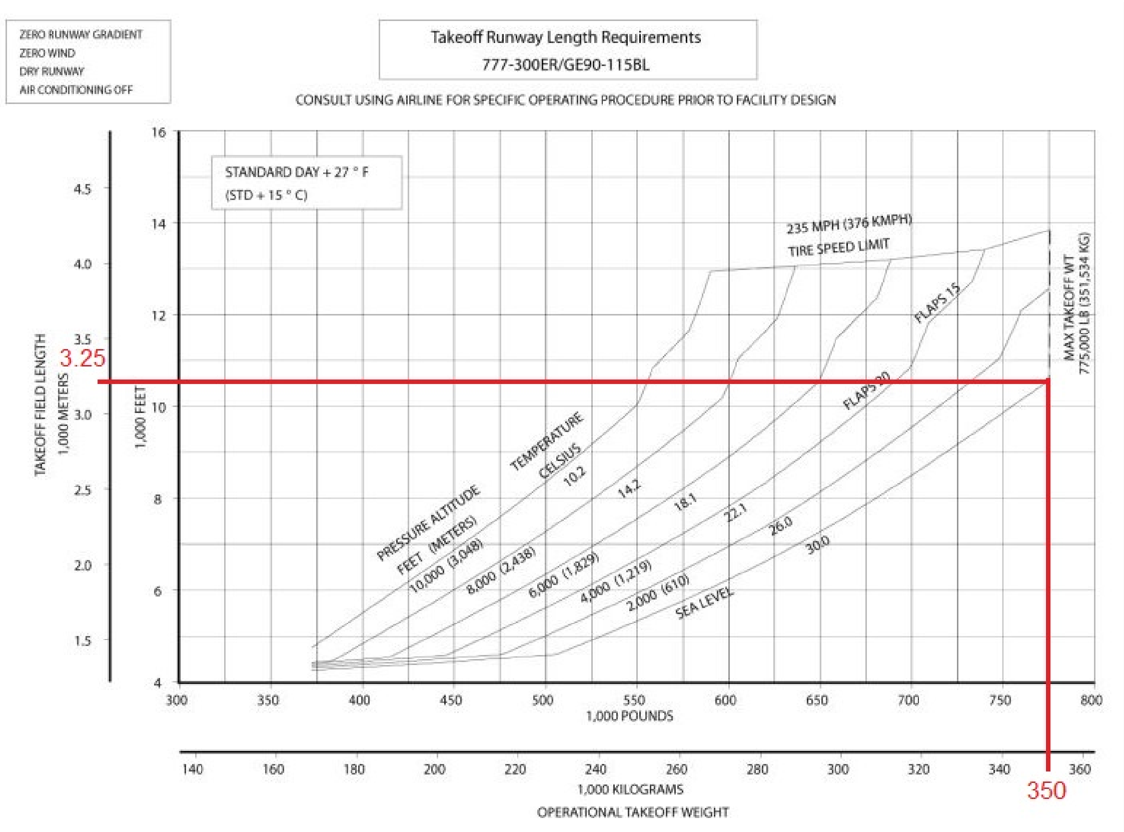

Figure 2.2.2: Relation between the MTOW and the takeoff distance.

As it is seen on the graph above, the length taken as reference (LCR) is 3.250m in a standard day+15ºC and sea level conditions.

The same procedure has to be done with the Airbus A330-300 in order to compare which one is the most restrictive one. Using the ACAP (Aircraft Characteristic for Airport Planning), the MTOW and MLW obtained are the following:

Aircraft Characteristics				
	WV000	WV001	WV002	WV003
Maximum Taxi Weight (MTW) Maximum Ramp Weight (MRW)	212 900 kg (469 364 lb)	184 900 kg (407 635 lb)	212 900 kg (469 364 lb)	215 900 kg (475 978 lb)
Maximum Take-Off Weight (MTOW)	212 000 kg (467 380 lb)	184 000 kg (405 650 lb)	212 000 kg (467 380 lb)	215 000 kg (473 994 lb)
Maximum Landing Weight (MLW)	174 000 kg (383 604 lb)	174 000 kg (383 604 lb)	177 000 kg (390 218 lb)	177 000 kg (390 218 lb)
Maximum Zero Fuel Weight (MZFW)	164 000 kg (361 558 lb)	164 000 kg (361 558 lb)	167 000 kg (368 172 lb)	167 000 kg (368 172 lb)

Figure 2.2.3: Maximum A330's weights.

Since the difference on the MTOW and MLW between both planes is greater than a 50%, the Boeing's Reference Field Length is chosen as the critical without calculating the Reference Field Length of the A330-300.

Once the most restrictive plane is chosen, the next step is to correct the length following ICAO's instructions. The equation used to correct the altitude difference is:

$$L_t = RFL * (1 + 0,07 * \frac{\Delta h}{300})$$

Solving the equation for a RFL of 3.250m and an increase on the altitude of 100m, the result obtained is 3326m. Since the temperature has already been corrected on the graph and the runway slope is going to be less than 0,5% and thus, it can be neglected, the final length will be 3.500m rounding up.

2.2.1.2 Reference code

Using the dimensions of the B777-300ER and the tables given by the ICAO, the number and letter that define the runway can be obtained.

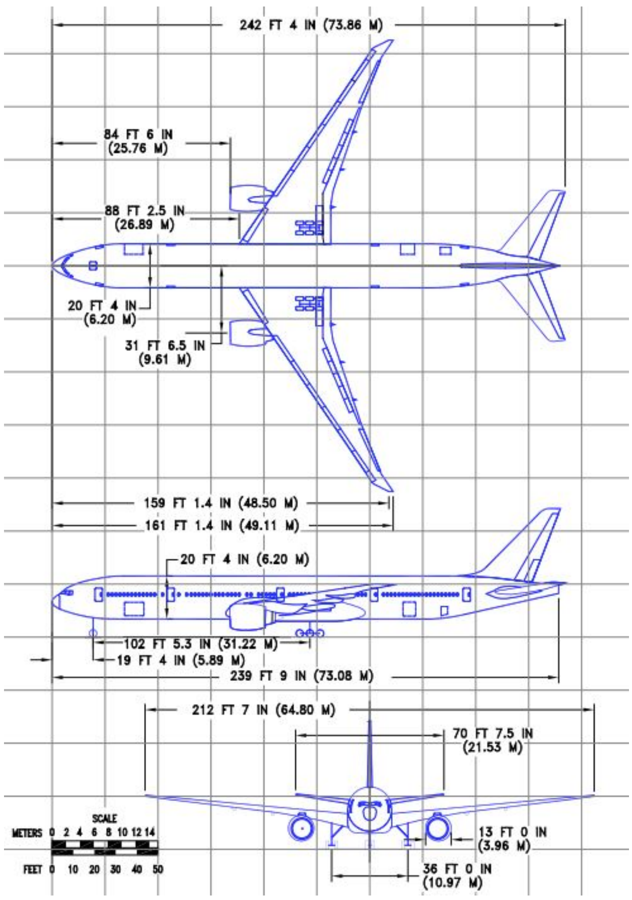

Figure 2.2.4: Boeing 777-300ER dimensions.

	Code element 1		Code element 2	
Code number (1)	Aeroplane reference field length (2)	Code letter (3)	Wingspan (4)	Outer main gear wheel span[a] (5)
1	Less than 800 m	A	Up to but not including 15 m	Up to but not including 4.5 m
2	800 m up to but not including 1 200 m	B	15 m up to but not including 24 m	4.5 m up to but not including 6 m
3	1 200 m up to but not including 1 800 m	C	24 m up to but not including 36 m	6 m up to but not including 9 m
4	1 800 m and over	D	36 m up to but not including 52 m	9 m up to but not including 14 m
		E	52 m up to but not including 65 m	9 m up to but not including 14 m
		F	65 m up to but not including 80 m	14 m up to but not including 16 m

a. Distance between the outside edges of the main gear wheels.

Figure 2.2.5: Reference code given by the ICAO.

Due to the RFL being higher than 1800m , the reference number of the runway is number 4 according to ICAO and due to the dimensions of the air plane B777-300ER, which has a span of 64,8m<65m and a distance between the landing gear of 10,97m<14m, the letter that defines the airport is E.

2.2.1.3 Runway's width and shoulders

The runway width is obtained using the ICAO recommendations stated on the Annex 14 and the key reference of the runway.

	Code letter					
Code number	A	B	C	D	E	F
1[a]	18 m	18 m	23 m	–	–	–
2[a]	23 m	23 m	30 m	–	–	–
3	30 m	30 m	30 m	45 m	–	–
4	–	–	45 m	45 m	45 m	60 m

Figure 2.2.6: Runway width according to ICAO.

As it can be seen, and remembering that our key reference is 4E, the minimum runway width needed is 45m. This value has to be further increased with the use of runway shoulders up to a minimum of 60m.

2.2.1.4 Declared distances

The calculations done in order to obtain the final value can be seen on the airside's attachments section 1.

To sum up, the final values obtained are:

Landing Distance Available	3.500m
TakeOff Distance Available (TODA)	4.460m
TakeOff Run Available (TORA)	3.760m
Accelerate-Stop Distance Available (ASDA)	4.360m

Table 2.2.1: Declared distances of Runway 1

An schematic figure will be attached in order to ease the understanding of the declared distances:

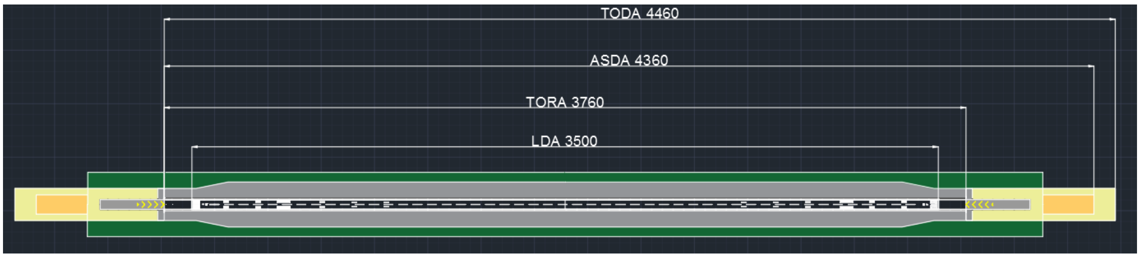

Figure 2.2.7: Declared distances on CAD.

2.2.1.5 Runway's strips

The strip is a delimited area of terrain centred in the runway that has the function of reducing the air plane's risk of getting out of the runway.

According to ICAO's rule number 3.4.2 and 3.4.3, all the runways with a reference number of 4 must contain a strip in each side of the runway's axis. The minimum distance has to be 150m and has to be extended a minimum of 60m after the threshold. Following the rule 3.4.8, the first 150m from the threshold have to be separated at least 75m form the runway's axis. Past those 150m, the strip has to grow linearly until reaching the strip levelled zone.

2.2.1.6 Runway's End Safety Areas (RESA)

According to ICAO's rule number 3.5.1, the airport with a reference number of 4 has to have a runway end safety area that should extend over a distance of at least 90m. Furthermore, as it is said in the point 3.5.5, the width of a runway end safety area shall be at least twice that of the associated runway.

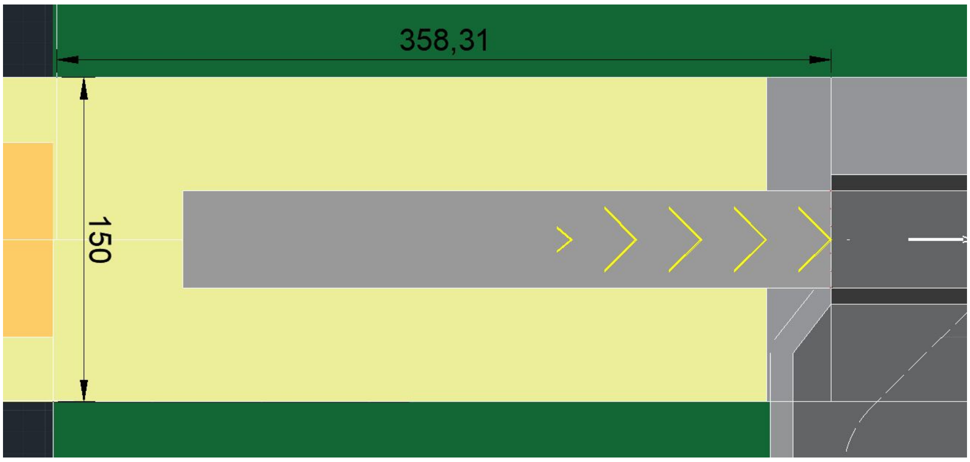

Figure 2.2.8: Runway End Safety Area for runway 1.

As it can be seen, the RESA starts at the end of the strip and its final dimensions are 360m length rounding up and 150m width.

2.2.1.7 Clearway (CWY)

Following the recommendation number 3.6.2 and 3.6.3, the Clearway has its beginning at the end of the maximum takeoff distance available and its maximum length should be half that distance.

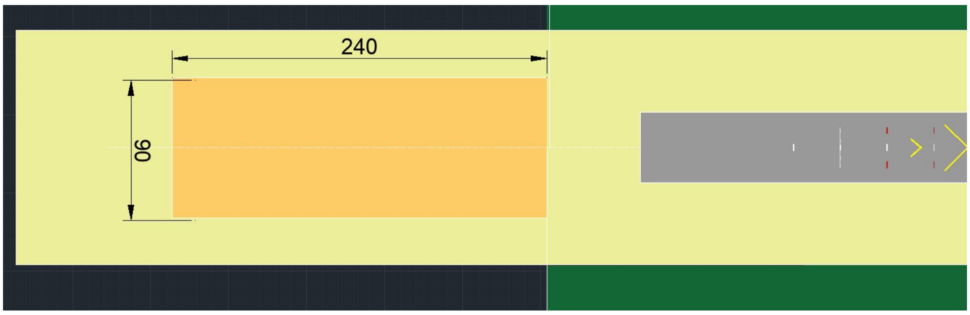

Figure 2.2.9: CWY placed at the end of runway 1.

The final dimensions of the CWY are: 240m length and 90m width.

2.2.1.8 Stopway (SWY)

When it comes to the stopway, following the ICAO's rules, the stopway shall have the same width as the runway with which it is associated.

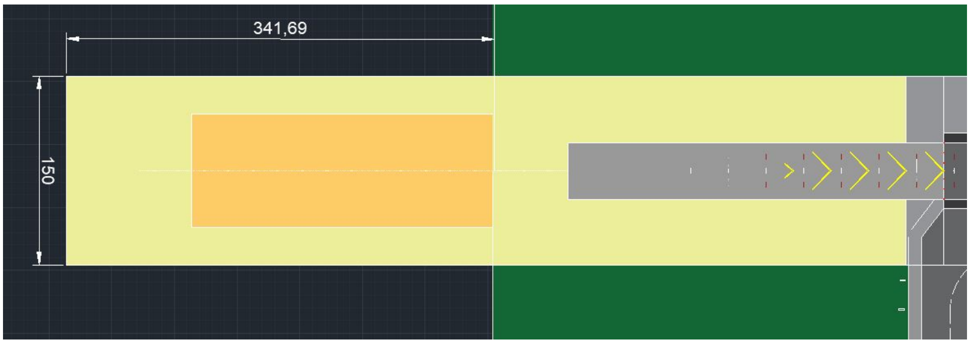

Figure 2.2.10: SWY positioning and dimensions.

As it can be seen, the final values for the SWY are 150m width and 341,69m length.

2.2.1.9 Pavement

The pavement chosen for the runways will be flexible since it can be easily maintained, it can be restored and there is no risk of fuel leaks during the takeoff and landing performance.

In order to gain a general idea of how the flexible pavement is and how does it work, an image will be attached:

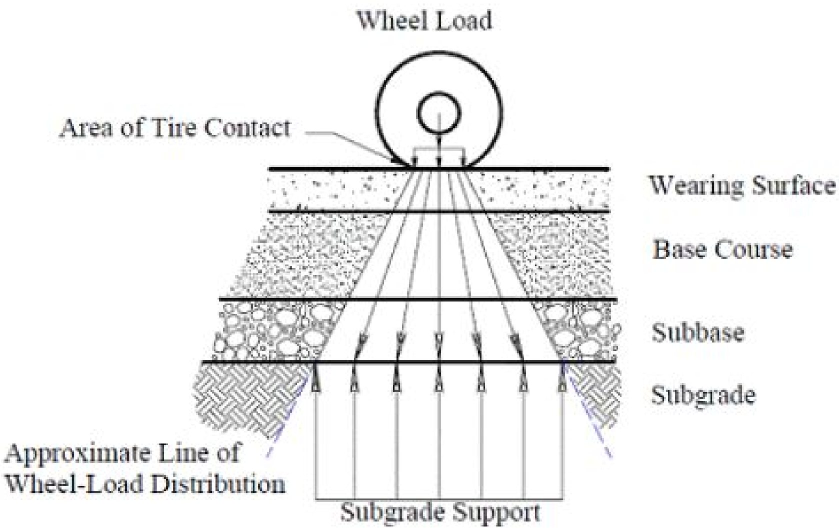

Figure 2.2.11: Flexible pavement layers and load distribution.

The thickness to be calculated are the wearing surface, the base course and the subbase whilst the subgrade is the natural ground of the area.

Due to the fact that there is a lot of calculations and graph's interpretation needed in order to calculate the pavement thickness, the explanation step by step will be done in the attachments, chapter 2 section 2. Thus, the only information related to the pavement thickness that will be shown in this section will be the final results obtained and gathered in the following table:

First layer's thickness (T_1)	14 cm
Second layer's thickness (T_2)	25 cm
Third layer's thickness(T_3)	65,5 cm
Total thickness (T_t)	104,5 cm

Table 2.2.2: Final values of total thickness and each layer's thickness.

2.2.2 Runway 2

In this case, since this runway is going to be used for domestic flights, the planes that are going to be evaluated are the Boeing 737-800 and the Airbus 320-200.

2.2.2.1 Reference Field Length

Searching the values of MTOW and MLW stated on the ACAP of the Boeing 737, the values obtained are 79.000kg for the MTOW and 66.300kg for the MLW.

CHARACTERISTICS	UNITS	MODEL 737-800, -800 WITH WINGLETS		
MAX DESIGN TAXI WEIGHT	POUNDS	156,000	173,000	174,900
	KILOGRAMS	70,760	78,471	79,333
MAX DESIGN TAKEOFF WEIGHT	POUNDS	155,500	172,500	174,200
	KILOGRAMS	70,534	78,245	79,016
MAX DESIGN LANDING WEIGHT	POUNDS	144,000	144,000	146,300
	KILOGRAMS	65,317	65,317	66,361
MAX DESIGN ZERO FUEL WEIGHT	POUNDS	136,000	136,000	138,300
	KILOGRAMS	61,689	61,689	62,732
OPERATING EMPTY WEIGHT (1)	POUNDS	91,300	91,300	91,300
	KILOGRAMS	41,413	41,413	41,413
MAX STRUCTURAL PAYLOAD	POUNDS	44,700	44,700	47,000
	KILOGRAMS	20,276	20,276	21,319
SEATING CAPACITY (1)	TWO-CLASS	160	160	160
	ALL-ECONOMY	184	184	184

Figure 2.2.12: Maximum weights of the B737 depending on its configuration.

As for the B777, the next step is to calculate using the following graph the takeoff distance required with standard day + 15ºC = 30ºC and sea level conditions using the MTOW.

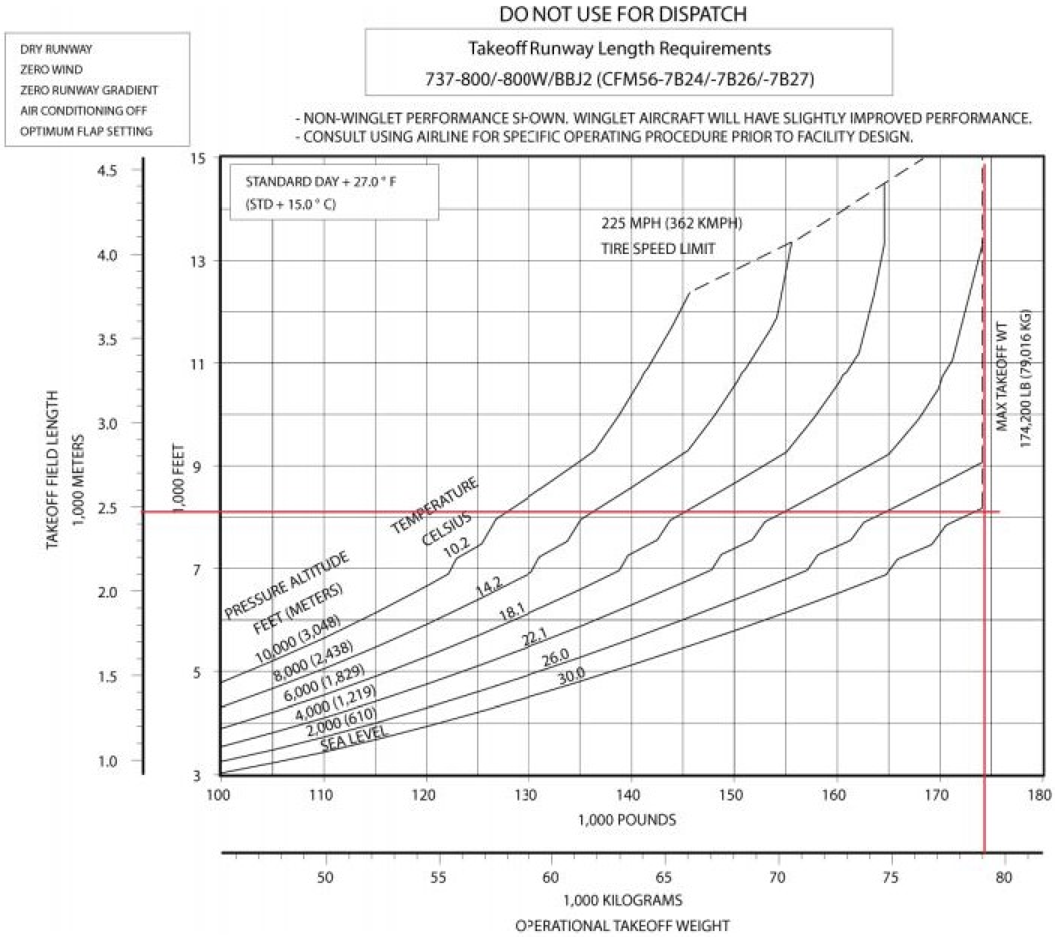

Figure 2.2.13: Relation between the MTOW and the takeoff distance.

The value of the RFL obtained is 2.450m approximately in standard day and sea level conditions.

The same procedure has to be done with the Airbus A320-200 in order to compare which one is the most restrictive one. Using the ACAP (Aircraft Characteristic for Airport Planning), the MTOW and MLW obtained are the following:

Aircraft Characteristics					
	WV000	WV001	WV002	WV003	WV004
Maximum Ramp Weight (MRW) Maximum Taxi Weight (MTW)	73 900 kg (162 922 lb)	68 400 kg (150 796 lb)	70 400 kg (155 205 lb)	75 900 kg (167 331 lb)	71 900 kg (158 512 lb)
Maximum Take-Off Weight (MTOW)	73 500 kg (162 040 lb)	68 000 kg (149 914 lb)	70 000 kg (154 324 lb)	75 500 kg (166 449 lb)	71 500 kg (157 630 lb)
Maximum Landing Weight (MLW)	64 500 kg (142 198 lb)	64 500 kg (142 198 lb)	64 500 kg (142 198 lb)	64 500 kg (142 198 lb)	64 500 kg (142 198 lb)
Maximum Zero Fuel Weight (MZFW)	60 500 kg (133 380 lb)	60 500 kg (133 380 lb)	60 500 kg (133 380 lb)	60 500 kg (133 380 lb)	60 500 kg (133 380 lb)

Figure 2.2.14: Maximum weights of the A320 depending on its configuration.

Due to the fact that the MTOW and the MLW of the B737 are higher than the A320 ones, the plane B737 is chosen as the critical for the design of the runway.

The next step is to correct the field length using the equation stated above, on the calculations for runway 1.

$$L_t = RFL * (1 + 0,07 * \frac{\Delta h}{300})$$

Solving the equation for a RFL of 2.450m and an increase on the altitude of 100m, the result obtained is 2500m. The same hypotheses used on the runway number 1 will be applied regarding the temperature and slope of the runway. Thus, the final length will be 2500m.

2.2.2.2 Reference code

Using the dimensions of the B737-800 and the tables given by the ICAO, the number and letter that define the runway can be obtained.

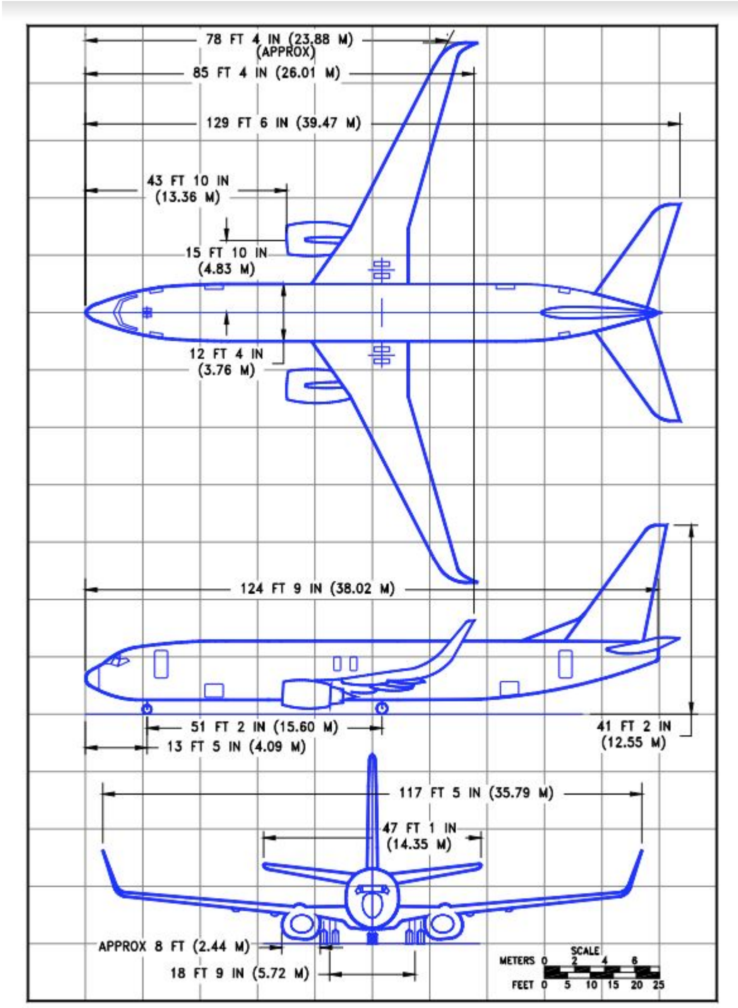

Figure 2.2.15: Boeing 737-800 dimensions.

Due to the RFL being higher than 1800m , the reference number of the runway is 4 according to ICAO and due to the dimensions of the air plane B737-800, which has a span of 35,8m<36m and a distance between the landing gear of 6m<9m, the letter that defines the airport is C.

2.2.2.3 Runway's width and shoulders

The runway width is obtained using the ICAO recommendations stated on the Annex 14 and the key reference of the runway.

Code number	Code letter A	B	C	D	E	F
1^a	18 m	18 m	23 m	–	–	–
2^a	23 m	23 m	30 m	–	–	–
3	30 m	30 m	30 m	45 m	–	–
4	–	–	45 m	45 m	45 m	60 m

Figure 2.2.16: Runway width according to OACI.

As it can be seen, and remembering that our key reference is 4C, the minimum runway width needed is 45m. This value has to be further increased with the use of runway shoulders up to a minimum of 60m.

2.2.2.4 Declared distances

As for the runway 1, the calculations done in order to obtain the final value can be seen on the airside's attachments section 1.

To sum up, the final values obtained are:

Landing Distance Available	2.500m
TakeOff Distance Available (TODA)	3.120m
TakeOff Run Available (TORA)	2.750m
Accelerate-Stop Distance Available (ASDA)	2.900m

Table 2.2.3: Declared distances of Runway 2

2.2.2.5 Runway's strips

As for the runway 1, due to the fact that both runways share the same reference number and the legislation does not make any distinction using the reference letter, the dimensions of the strips of runway 2 are exactly the same as runway 1.

2.2.2.6 Runway's End Saefty Areas (RESA)

According to ICAO's rule number 3.5.1, the airport with a reference number of 4 has to have a runway end safety area that should extend over a distance of at least 90m. Furthermore, as it is said in the point 3.5.5, the width of a runway end safety area shall be at least twice that of the associated runway.

2.2.2.7 Clearway (CWY)

In this case, the clearway dimensions and position is the following:

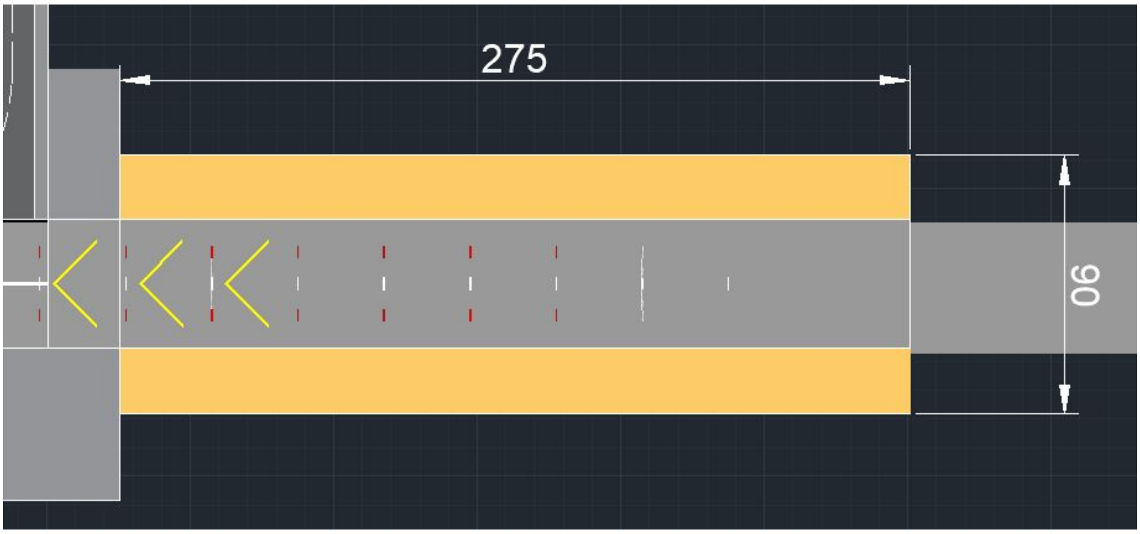

Figure 2.2.17: CWY placed at the end of runway 2.

2.2.2.8 Pavement

The pavement chosen for the runway 2 will be flexible since it can be easily maintained, it can be restored and there is no risk of fuel leaks during the takeoff and landing performance.

As it was said before, the calculations and graph interpretations for the final runway thickness are further explained in the attachments chapter 2 section 2. Thus, the only information that will be shown in this section will be the final results gathered in the following table:

First layer's thickness (T_1)	143 cm
Second layer's thickness (T_2)	23 cm
Third layer's thickness(T_3)	55,5 cm
Total thickness (T_t)	91,5 cm

Table 2.2.4: Final values of total thickness and each layer's thickness.

3 | Taxiway design

3.1 Introduction

The aim of the taxiways is to link the different parts of the airport such as the different runways, the terminal, hangars or the parking lot. Several factors must be taken into account when designing this part of the airside; it goes without saying that this design must make the operations easy, efficient and must minimise the total amount of crosses in the flows and in the traffic.

3.2 Taxiway's width

OACI's Annex 14 states that, depending of the code letter, the width must be, at least:

Code letter	Taxiway width [m]
A	7,5
B	10,5
C	15
D	18-23
E	23
F	25

Table 3.2.1: Taxiway width depending on its code letter.

Due to the fact that our airport has 2 different runways, thus, two different code letters. Thus, the international runway will have a taxiway of 23m since its code letter is E and the domestic one will have 17m since its category is C.

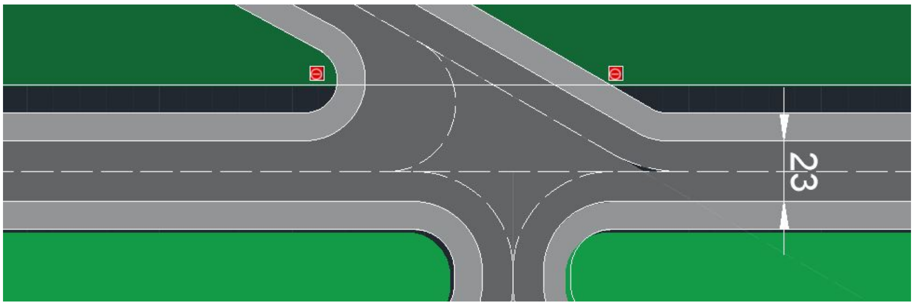

Figure 3.2.1: Example of the width on the taxiway of runway 1.

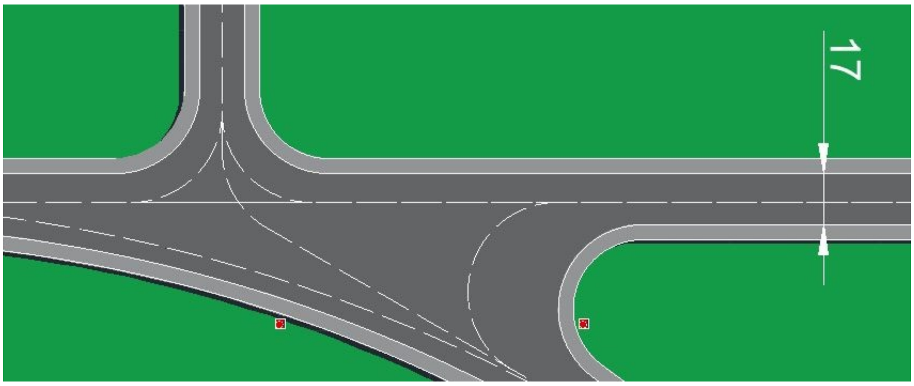

Figure 3.2.2: Example of the width on the taxiway of runway 2.

3.3 Taxiway's turns

Even though it is recommended that the fewer changes in direction, the better, the Annex 14 stipulates that, for a plane that remains over the taxiway centre line markings, the distance between the outer main wheel and the edge of the taxiway should be, at least:

Code letter	Clearance [m]
A	1,5
B	2,25
C	3-4,5
D	4,5
E	4,5
F	4,5

Table 3.3.1: Clearance depending on its code letter.

For the international runway, the clearance will be 4,5m and 3m for the domestic flights runway.

3.4 Minimum separation distance

Taking the axis of the taxiway and the axis of the runway or any other taxiway as the reference elements of both paths, under no circumstances should the distance between them be less than the ones shown in table 3.1 in Annex 14 (unless an existing minor distance is proven not to affect negatively the security of the system).

3.5 Taxiway's slope

In this section, the taxiway's slope will be boarded, trying to bring solutions in case that the slope can't be changed.

3.5.1 Longitudinal slope

The longitudinal slope of a taxiway should never exceed:

- 1,5% if the code letter is C, D, E or F.

- 3% if the code letter is A or B.

Even though the longitudinal slope has to be tried to be reduced to a minimum, the final longitudinal slope will be 1% on each runway.

3.5.2 Change of the longitudinal slope

If it is not possible to prevent the change of the slope in a taxiway, the transition among them should be a curved surface which curvature should not exceed:

- 1% for every 30m (radius of curvature approximately 3.000 m) if the code letter is C, D, E or F.

- 1% for every 25m (radius of curvature approximately 2.500 m) if the code letter is A or B.

Since the longitudinal slope is within the limits established by the ICAO's recommendations, there is not going to be any local change of the longitudinal slope.

3.5.3 Visible distance

If changing the slope patterns in a taxiway is not possible, the change in slope should be the one that, from a point situated in:

- 3 m above the taxiway, it could be possible to see a surface of 300 m if the code letter is C, D E or F.

- 2 m above the taxiway, it could be possible to see a surface of 200 m if the code letter is B.

- 1,5 m above the taxiway, it could be possible to see a surface of 150 m if the code letter is A.

3.5.4 Transversal slope

The cross slope of a taxiway, as in runways, should be strong enough to prevent the accumulation of water in its surface, but should never be greater than:

- 1,5% if the code letter is C, D, E or F.

- 2% if the code letter is A or B.

The transversal slope selected for both taxiways is 1,5%.

3.6 Taxiway's shoulders

OACI's Annex 14 recommends that taxiways subordinated to runways with code letter C, D, E or F should be designed with symmetrical margins, in order to make the total width of the taxiway, that is to say, taxiway and margins, greater than:

- 60 m if the code letter is F.

- 44 m if the code letter is E.

- 38 m if the code letter is D.

- 25 m if the code letter is C.

An additional width should be added in curves, unions and intersections.

Following the recommendation shown above, the taxiway's shoulders of runway 1 will be 44m and the taxiway's shoulders of runway 2 will be 27m.

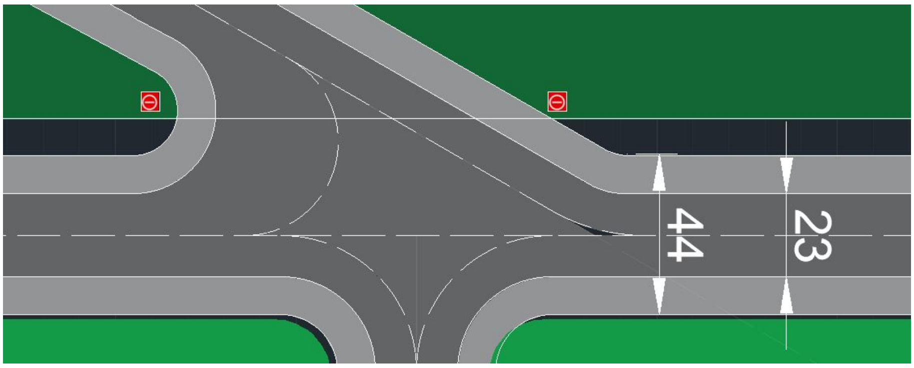

Figure 3.6.1: Example of the shoulders distance on the taxiway of runway 1.

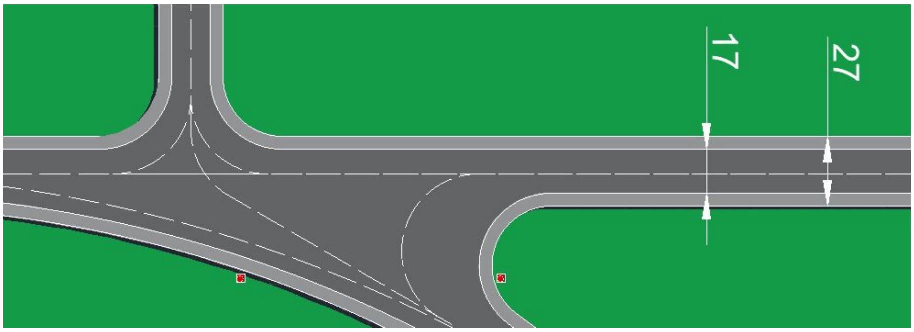

Figure 3.6.2: Example of the shoulders distance on the taxiway of runway 2.

3.7 Rapid exit taxiways

As a recommendation, a rapid-exit taxiway should be calculated with a turn radius of, at least:

- 550 m if code number 3 or 4.

- 275 m if code number 1 or 2.

In order to make the exit possible with a wet pavement at a speed of;

- 93 km/h if code number 3 or 4.

- 65 km/h if code number 1 or 2.

Moreover, the angle of rapid-exit taxiways should be comprehended between 45° and 25°, preferably 30°. Rapid-exit taxiways should also include a straight section in order to allow the air plane to reduce its speed.

4 Holding positions

4.1 Introduction

4.2 Minimum distance between holding position and runway

4.3 Interference with critical and ILS sensible areas

4.4 Interference with CWY and physical obstacles

4.4.1 Separation between aircraft (guardas entre aeronaves)

4.5 Final design of holding positions

5 | Apron design

5.1 Introduction

The apron is the area of an airport where the aircraft are parked, unloaded or loaded, refuelled and boarded. It also has to cover the taxiways and the trajectories that air planes have to take in order to get to the principal taxiways or the station zones.

Another function that the apron has to full-fill is the creation of a service way that will allow all the different services needed by the plane to get to it and the creation of some waiting positions for them that will not obstacle the manoeuvres of the plane. Last but not least, the connection between air-side and land-side is under the responsibility of the apron.

Before moving into a more detailed explanation of each part that makes the apron, a general view is going to be attached in order to obtain a general idea of what is the apron.

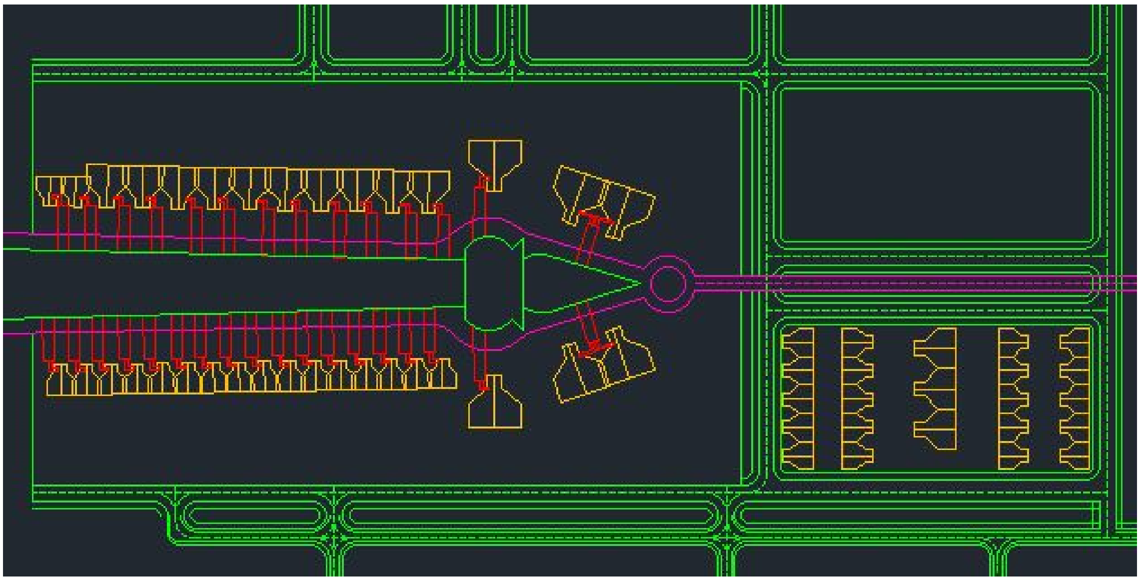

Figure 5.1.1: Apron simplified general view.

The sections of the apron that will be further explained are the apron taxiways, the aircraft stands, the apron trajectories, service ways and terminal connections.

5.2 Apron taxiways

Apron taxiways are designed in order to allow the aircraft to move from the principal taxiway to its specific apron. Due to the fact that our airport has two runways, the number of auxiliary taxiways is higher than a simpler airport. However, ICAO does not have a different criteria for these taxiways. Thus, the parameters and restrictions that apply on the auxiliary taxiways is the same than the principal ones.

Even though the airport is divided in two differenced parts, the domestic flights which have the B737 as most restrictive aircraft and the internationals flights with the B777 as critical air plane, the auxiliary taxiways are designed in order to allow the B777 to operate in the whole airport.

The line that limits the space where aircraft are allowed to taxi is an orange line surrounded by two white lines as it is stated on the ICAO's manual. Since the most restrictive reference letter is E, as it can be seen in the table attached below, the minimum distance between the taxiway's axis is 80m.

Code letter	Distance between taxiway centre line and runway centre line (metres)								Taxiway centre line to taxiway centre line (metres)	Taxiway, other than aircraft stand taxilane, centre line to object (metres)	Aircraft stand taxilane centre line to aircraft stand taxilane centre line (metres)	Aircraft stand taxilane centre line to object (metres)
	Instrument runways Code number				Non-instrument runways Code number							
	1	2	3	4	1	2	3	4				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
A	82.5	82.5	–	–	37.5	47.5	–	–	23	15.5	19.5	12
B	87	87	–	–	42	52	–	–	32	20	28.5	16.5
C	–	–	168	–	–	–	93	–	44	26	40.5	22.5
D	–	–	176	176	–	–	101	101	63	37	59.5	33.5
E	–	–	–	182.5	–	–	–	107.5	76	43.5	72.5	40
F	–	–	–	190	–	–	–	115	91	51	87.5	47.5

Note 1.— The separation distances shown in columns (2) to (9) represent ordinary combinations of runways and taxiways. The basis for development of these distances is given in the Aerodrome Design Manual *(Doc 9157), Part 2.*

Note 2.— The distances in columns (2) to (9) do not guarantee sufficient clearance behind a holding aeroplane to permit the passing of another aeroplane on a parallel taxiway. See the Aerodrome Design Manual *(Doc 9157), Part 2.*

Figure 5.2.1: Design distances for taxiways according to ICAO.

5.3 Aircraft stands

5.3.1 General dimensions of aircraft stands

In order to dimension the aircraft stands, the dimensions of the aircraft stated on their ACAP and the ICAO's recommendations have been followed. Starting with the recommendation, the following table shows the distance depending on the reference letter of the air plane.

Code letter	Clearance
A	*3 m*
B	*3 m*
C	*4.5 m*
D	*7.5 m*
E	*7.5 m*
F	*7.5 m*

Figure 5.3.1: Clearance distances depending on the reference letter.

In order to understand how the aircraft stands are shaped, the following image is attached:

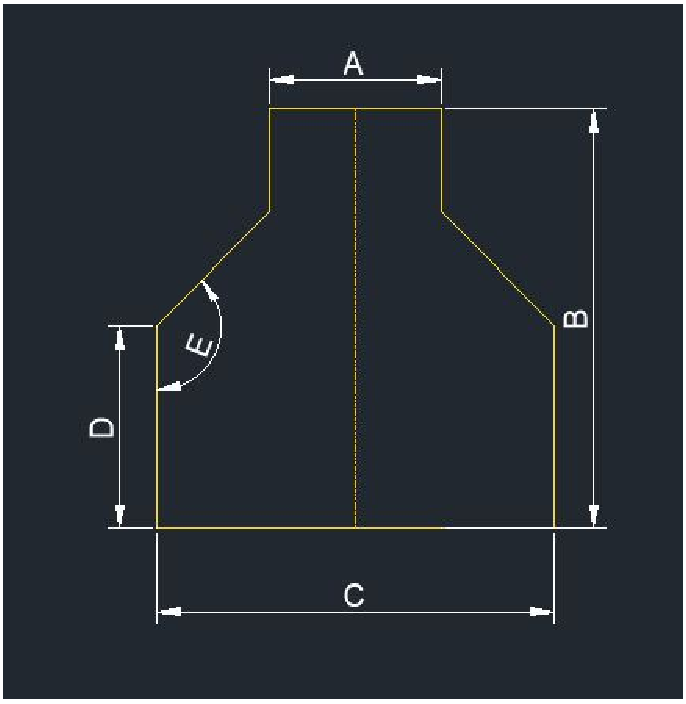

Figure 5.3.2: Clearance distances depending on the reference letter.

The next step is to explain how can each distance be obtained:

- A: this distance can be calculated by adding the maximum width of the air plane and the security margin stated on the table attached above.

- B: It can be dimensioned by adding two times the security margin stated by ICAO's recommendation and the aircraft length. The security margin is considered two times since the distance has to be respected in the front part and the rear part of the air plane.

- C: Once more, this distance can be obtained by adding the security margin on each side and the air plane's span.

- D: This distance can be calculated picking up the distance form C until the last airfoil and adding the contribution of the security margin.

- E: This distance required is geometrically more complex and can be obtained by creating a parallel line distanced the security margin from the line created from the tip of the last airfoil until the edge of the engine.

5.3.2 Dimensions for reference aircraft

Before stating all the distances, a reference point must be set. The centre of coordinates is placed in the nose of the plane, the x-axis is considered positive following the aircraft's direction, the y-axis is considered positive in the direction of the left half-wing and the z-axis is oriented to the ground.

5.3.2.1 B777

The dimensions of the air plane B777 are the following:

Span	64,8m
Length	73,86m
Length last airfoil	0,6m
Engine position x	25,76m
Wing tip coordinate	49,11m

Table 5.3.1: Boeing 777 distances and dimensions.

The security margin used on the B777 according to ICAO's table is 7,5m.

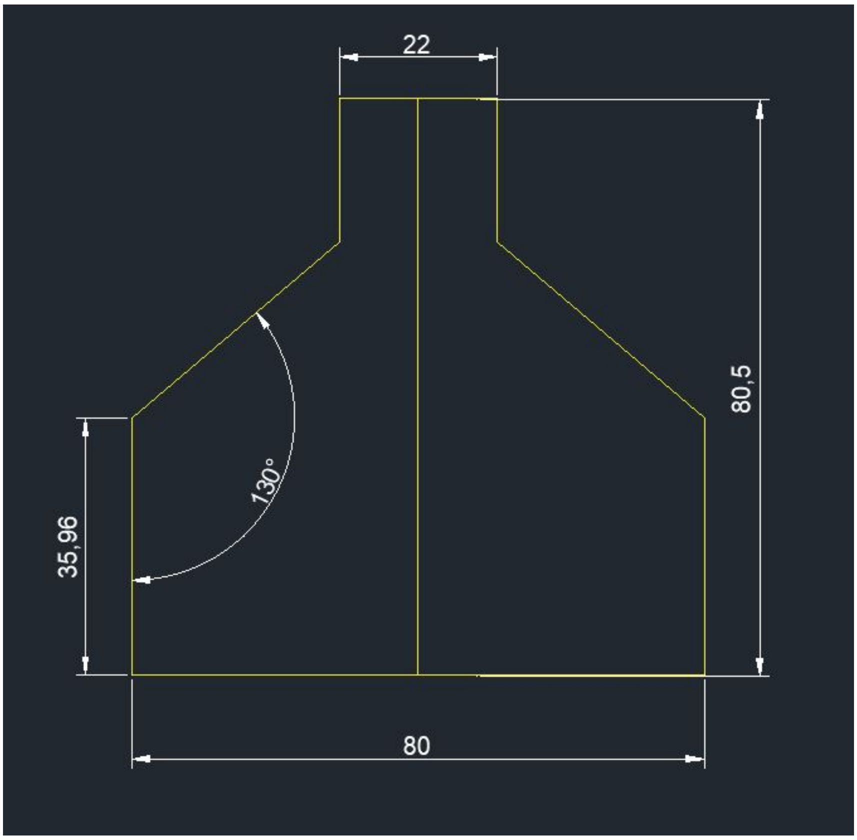

Figure 5.3.3: B777 aircraft stand dimensions.

5.3.2.2 B737

Doing the same for the B737, the table obtained is the following:

Span	35,79m
Length	39,47m
Length last airfoil	2,13m
Engine position x	13,36m
Wing tip coordinate	23,88m

Table 5.3.2: Boeing 737 distances and dimensions.

The security margin used on the B737 according to ICAO's table is 4,5m. The next image shows the B737 aircraft's stand:

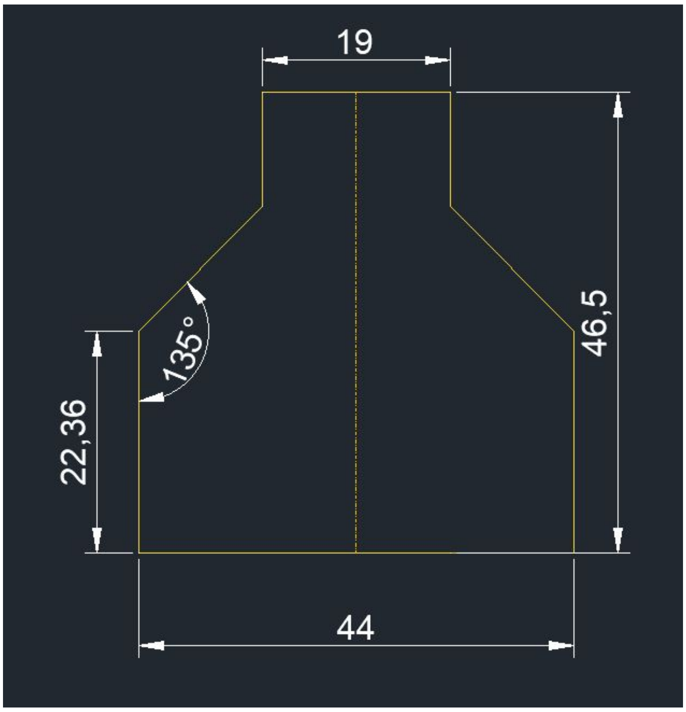

Figure 5.3.4: B737 aircraft stand dimensions.

5.4 Service ways in apron

The service ways are used for different vehicles in order to complete a mission in a plane or in another place of the apron. The legislation followed by this type of road depends on the General Traffic Direction. In order to ease the procedures, the legislation that will be followed is the one stated on the Real Decreto 2086/2011 published by the Spanish General Traffic Direction.

The most restrictive vehicle that will use the service ways is the truck. Following the legislation mentioned above, the minimum radius is 12,8m. The total width chosen in order to facilitate and increase the security on those vehicles is 21m, 10,5m for each direction.

As it can be seen on the drawings, the service way is designed in order to supply both the apron and the remote taxi ways. Due to the fact that the service way goes across with the auxiliary taxiways, the legislation states that two signs which guarantee aircraft preference over the other vehicles are a must in the intersection points. In addition, a sign that reminds the drivers to be careful with the jet-blast gases of the air planes is required. The signs used are shown below:

Figure 5.4.1: Sign that informs of an intersection with an aircraft.

Figure 5.4.2: Sign that informs of Jet Blast.

Furthermore, the way has to be supplied with the general traffic signs following the Spanish GTD.

The next image shows the final design of the service way in purple colour. It surrounds the terminal in order to supply the planes parked on the apron and also extends until the remote parking area in order to supply the other aircraft.

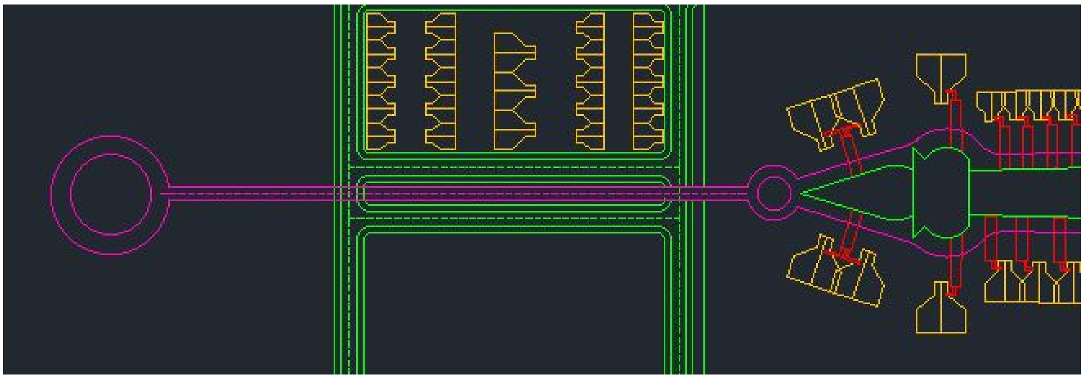

Figure 5.4.3: Final desgin of the service way.

5.5 Terminal connections

In this section, the connection with fingers between the planes and the terminal will be explained.

Due to the fact that our terminal has two floors, the lower one for the arrivals and the upper for the departures, an auxiliary structure before the finger is needed in order to ease the boarding procedure. This structure will be used in order to manage and distribute the flux of passenger entering and exiting the air plane. The departure passengers will start in the upper level and will be able to board directly using the finger. However, the procedure is different during the exit of the plane. Once the passengers have left the air plane and the finger, they will be required to get down to the lower floor using an escalator placed on the auxiliary structure. Thus, they will enter the terminal directly on the arrivals floor.

There is a total number of 28 fingers and they are placed as its shown:

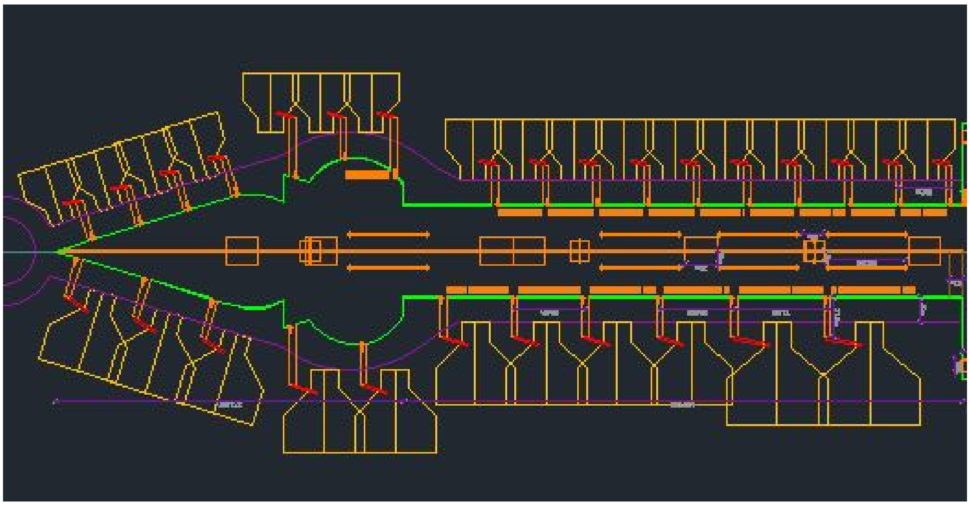

Figure 5.5.1: General view of all the fingers connected to the terminal.

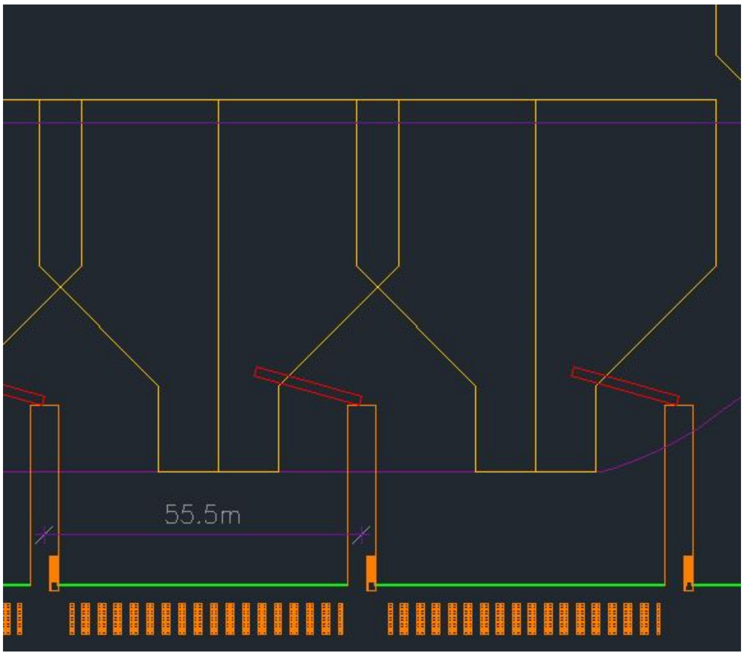

Figure 5.5.2: Close up view of some Boeing 737 stands with their respective finger connection.

5.6 Pavement

The type of pavement selected for the apron will be rigid. The main reason behind that decision is the fact that it can resist the chemical erosion and corrosion done by the fuel in case of any possible leak.

Since the calculations and interpretations of graphs used in order to calculate the cement thickness are quite long and complex, the process step by step will be shown in the attachments whilst the only information given in the report will be the final thickness.

Thus, moving on into the results, the final thickness obtained for the cement slab is $T_{slab} = 51cm$

6 | Markings

6.1 Introduction

As a general rule, and if it is not said otherwise, in the event of an intersection, the most important way will interrupt the other ways' central axis in order to make its own prevail. Apart from the most obvious classification, the hierarchy will be:

- Precision approximation runways

- Normal approximation runways

- Visual flight runways

Colours of the markings

Runway: The colour used in the marking of the runway will be white. They can be surrounded by dark markings in order to increase their visibility.

Taxiway, apron and turn runway platforms: The colour used in those airport sectors will be yellow.

Safety platform lines: They do not have an specific colour, but it will be different form the two mentioned above in order to differentiate them easily.

6.2 Runway's markings

6.2.1 Runway's centreline markings

The markings will be placed as the figure shown above suggests. With an interval (line plus space) comprehended between 50m and 75m and a width of 0,45m in both runways since they are the same category.

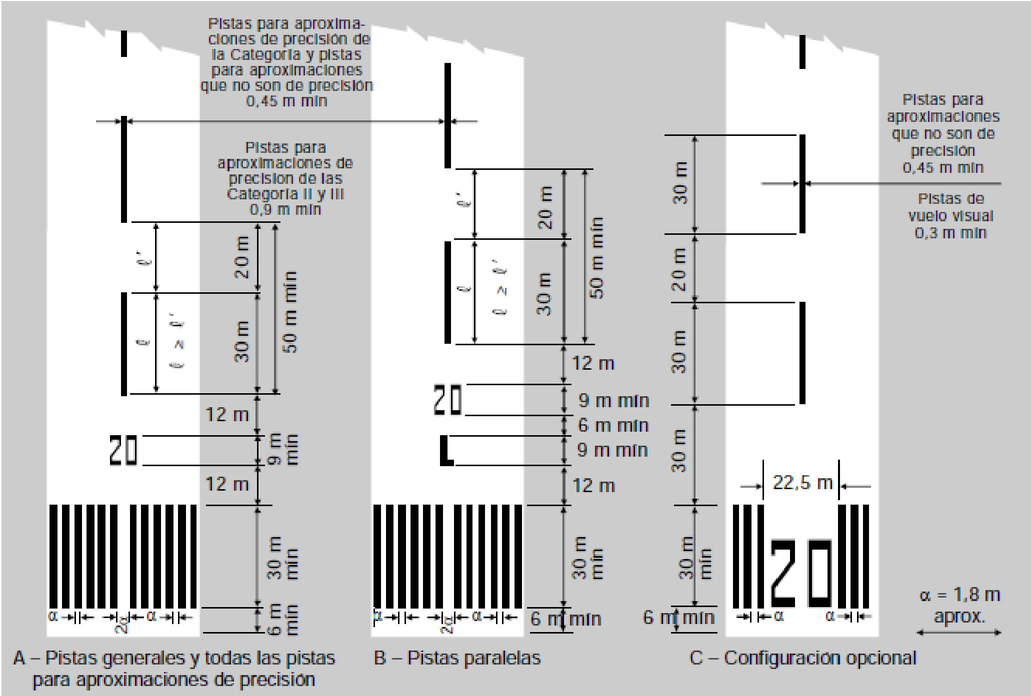

Figure 6.2.1: Centreline according to ICAO's recommendations.

Due to the fact that the airport has two parallel runways, the model used will be the middle one.

The following figure attached will be shown as an example:

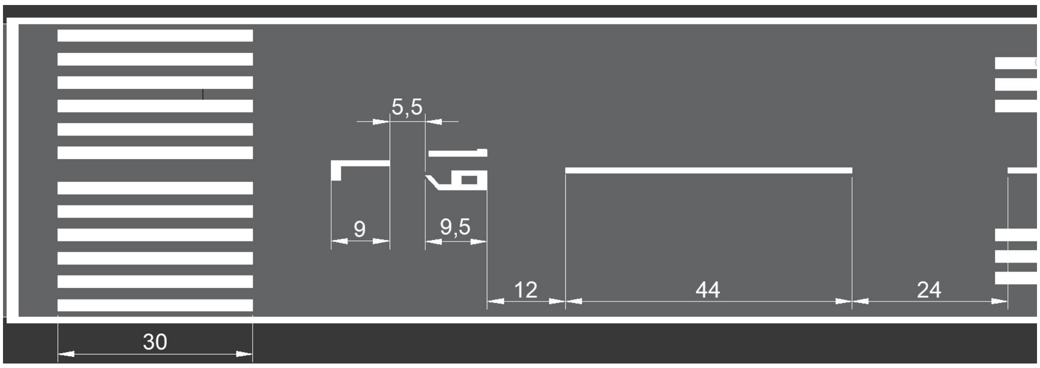

Figure 6.2.2: Centre line of the international runway.

6.2.2 Runway's threshold markings

The strips that indicate the start of the threshold will start at 6 m from the beginning of the threshold, and will contain 12 stripes, choosing the configuration specified in the Annex 14 part 5.2.4.6., including a minimum of 30m of length and 1,80m of width, with a separation of approximately 1,80m.

6.2.2.1 Arrows

The runway's aiming point markings will be placed if the threshold is displaced from the runway extreme. As in the case of the Bekasi-East Jakarta both runways (4E and 4C) the threshold will be displaced, they are a must. They will be coloured in white.

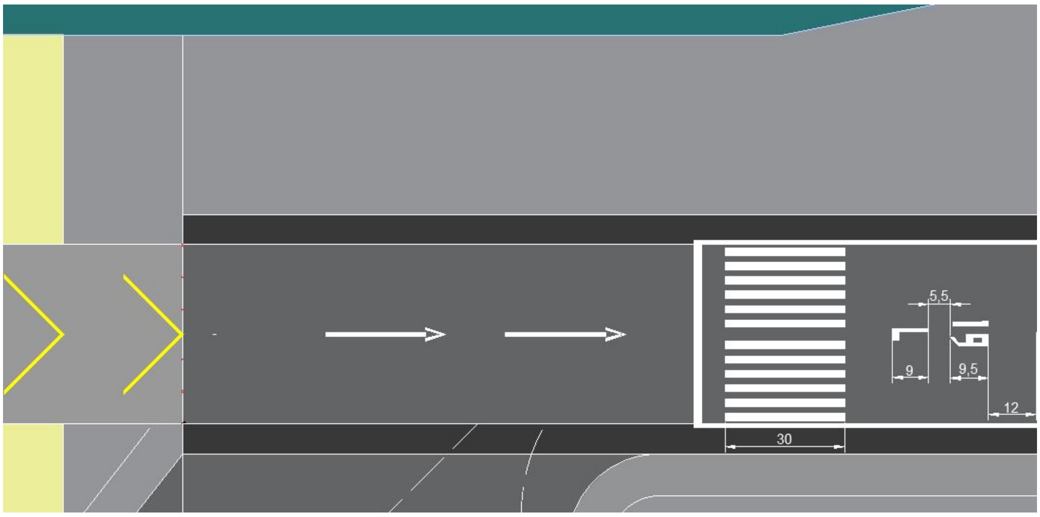

Figure 6.2.3: Example of arrows pointing at the threshold.

6.2.3 Runway's designation marking

It will be placed in the threshold and in the case of Jakarta airport will be mandatory in all the cases as they all are paved. This designer will consist in two numbers referred to the azimuthal position. This number will be accompanied by a letter, indicating the order of appearance.

6.2.4 Runway's aiming point markings

As both runways meet the criteria, an aiming point is needed. The following table extracted from the annex 14 will show us which parameters should the aiming point mark have depending on the runway's category:

	Landing distance available			
Location and dimensions (1)	Less than 800 m (2)	800 m up to but not including 1 200 m (3)	1 200 m up to but not including 2 400 m (4)	2 400 m and above (5)
Distance from threshold to beginning of marking	150 m	250 m	300 m	400 m
Length of stripe[a]	30–45 m	30–45 m	45–60 m	45–60 m
Width of stripe	4 m	6 m	6–10 m[b]	6–10 m[b]
Lateral spacing between inner sides of stripes	6 m[c]	9 m[c]	18–22.5 m	18–22.5 m

a. The greater dimensions of the specified ranges are intended to be used where increased conspicuity is required.
b. The lateral spacing may be varied within these limits to minimize the contamination of the marking by rubber deposits.
c. These figures were deduced by reference to the outer main gear wheel span which is element 2 of the aerodrome reference code at Chapter 1, Table 1-1.

Figure 6.2.4: Table gathering all the aiming point marking parameters.

So, since both runways have a RFL higher than 2400m, the distance between the threshold and the start of the marking will be at 400 m, with a length of 60 m, a width of 10 m and a separation of 18 m. The following figure may serve as an example:

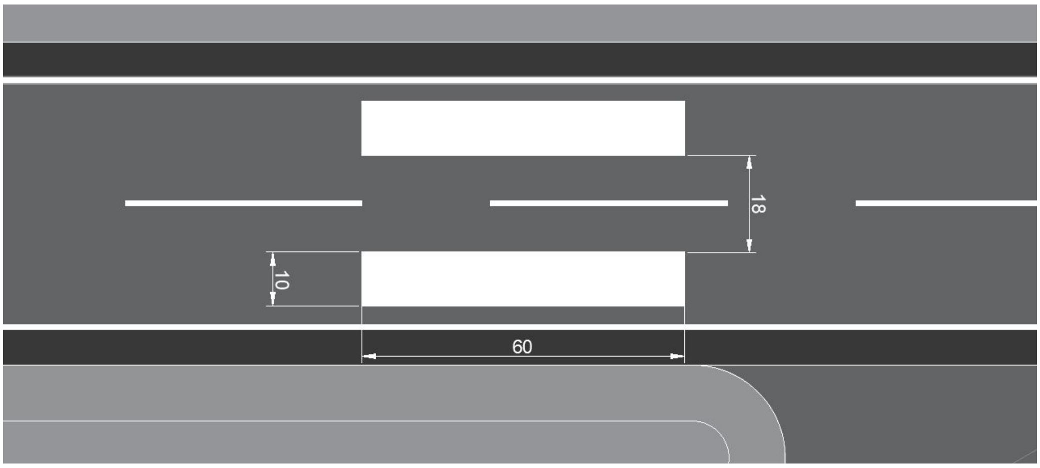

Figure 6.2.5: Example of aiming point markings placed in runway 1.

6.3 Taxiway's and holding position's markings

6.3.1 Introduction

Due to the fact that the airport being designed is a 4-type for both runways, the markings in the taxiways will be mandatory. The axis will be projected respecting the distances when curves appear and respecting the established hierarchy, that is to say, keeping in mind that they are subordinated to runways. The dimensions of this marking will be continuous and with 15cm of width at least, except in the event of an intersection.

6.3.2 Runway's entry holding position markings

The runway's entry holding position markings will be directly painted in the AutoCAD model following the regulations and recommendations stated in the annex 14.

6.3.3 Mandatory instruction markings

If there is no possibility of positioning a sign with mandatory indications, this indication will be painted in the pavement. In the case of the type C runway, this signal will be centred in the middle of the centreline, interrupting it, whereas in the type F runway the signal will be placed twice on each side of the axis.

The characters will be painted in white with a red background and the height of the different characters should be of, at least, 4m.

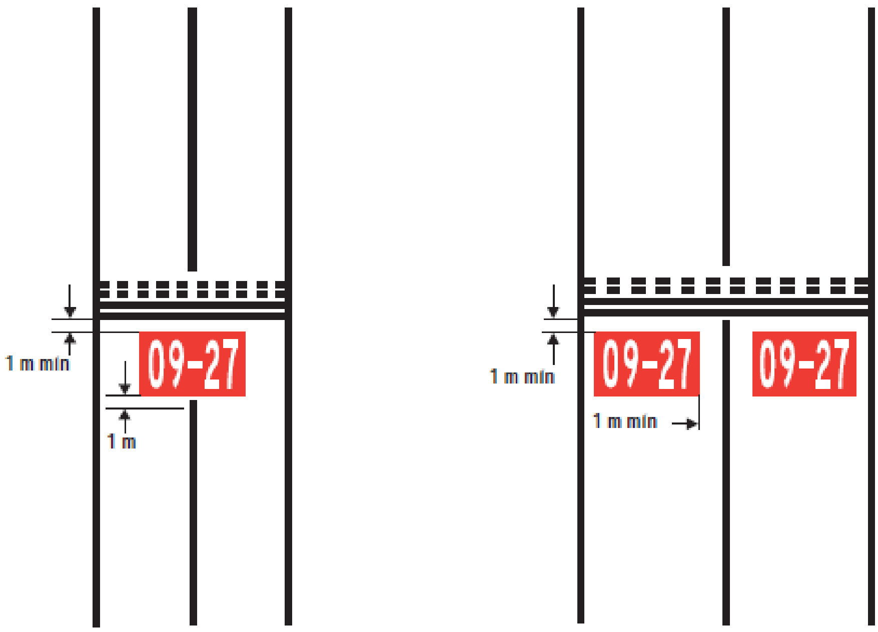

Figure 6.3.1: Design used in order to define the mandatory instruction markings.

6.3.4 Information markings

Depending of the information given, the colours of the information markings will be:

- Yellow characters with black background if it gives emplacement information.

- Black background with yellow background if it gives direction or destiny information.

6.4 Apron's markings

6.4.1 Introduction

They will include the identification number of every lot, with its guideline, alignment guide, stop line and departure line. The markings should be represented bearing in mind that the pilot should also be able to see the markings from the cabin. The guidelines should also be continuous with a width of, at least, 15cm, like the width of the alignment line in the final parking position.

6.4.2 Stand safety lines markings

When considered necessary, the platform surface may include a safe separation distance between the different aircraft, such as wing tip margin lines. They will be continuous with a width of, at least, 10cm.

7 | Lights

7.1 Runway lights

7.1.1 Approach lights

Due to the airport characteristics, it is defined as a precision approach runway II and III. According to that ICAO's classification, the starting point in order to design the approach lights is the rule 5.3.4.22.

The approach lighting system shall consist of a row of lights on the extended centre line of the runway, extending, wherever possible, over a distance of 900 m from the runway threshold. In addition, the system shall have two side rows of lights, extending 270 m from the threshold, and two crossbars, one at 150 m and one at 300 m from the threshold. Furthermore, the lights forming the centre line shall be placed at longitudinal intervals of 30 m with the innermost lights located 30 m from the threshold.

Moving into the point 5.3.4.24, the lights forming the side rows shall be placed on each side of the centre line, at a longitudinal spacing equal to that of the centre line lights and with the first light located 30 m from the threshold. Where the serviceability level of the approach lights specified as maintenance objectives in 10.5.7 can be demonstrated, lights forming the side rows may be placed on each side of the centre line, at a longitudinal spacing of 60 m with the first light located 60 m from the threshold. The lateral spacing between the innermost lights of the side rows shall be not less than 18 m nor more than 22.5 m, and preferably 18 m, but in any event shall be equal to that of the touchdown zone lights.

Both points 5.3.4.25 and 5.3.4.27 are related to the crossbars. The crossbar provided at 150 m from the threshold shall fill in the gaps between the centre line and side row lights while the one provided at 300m shall extend on both sides of the centre line lights to a distance of 15 m from the centre line.

The next image taken from annex 14 sums up all the points and requirements stated above:

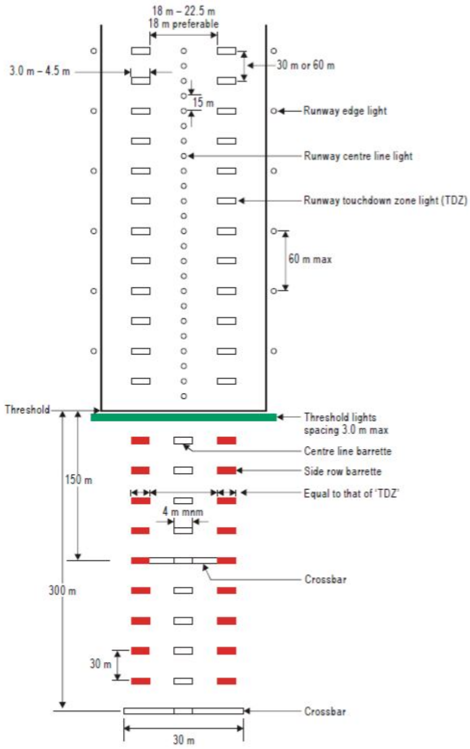

Figure 7.1.1: Schematic figure representing the approaching lights.

Characteristics

According to ICAO, the centre line of a precision approach category II and III lighting system for the first 300 m from the threshold shall consist of barrettes showing variable white, except that, where the threshold is displaced 300 m or more, the centre line may consist of single light sources showing variable white.

Since the threshold of both runways is not displaced more than 300m, the centre line will consist of barrettes showing variable white. Those barrettes has to have a minimum length of 4m according to the article number 5.3.4.33.

The side row shall consist of barrettes showing red. The length of a side row barrette and the spacing of its lights shall be equal to those of the touchdown zone light barrettes.

7.1.2 Approach slope indication systems

There are 4 types of approach slope indication systems: T-VASIS, AT-VASIS, PAPI AND APAPI. Depending on the system chosen, the design may change. In order to ease the maintenance costs and due to its easy design and installation, the system chosen is the PAPI. The recommendations and the rules that affect the PAPI and APAPI design range from the statement number 5.3.5.24 until the 5.3.5.41 inclusive.

Description

The PAPI system shall consist of a wing bar of four sharp transition multi-lamp units equally spaced and the system shall be located on the left side of the runway unless it is physically impracticable to do so.

The wing bar of a PAPI shall be constructed and arranged in such a manner that a pilot making an approach will:

a) When on or close to the approach slope, see the two units nearest the runway as red and the two units farthest from the runway as white.

b) When above the approach slope, see the one unit nearest the runway as red and the three units farthest from the runway as white; and when further above the approach slope, see all the units as white.

c) When below the approach slope, see the three units nearest the runway as red and the unit farthest from the runway as white; and when further below the approach slope, see all the units as red.

Calculations

The location of the PAPI system should be the one that brings the highest compatibility with all the other visual and non-visual factors, considering facts such has the vertical distance of the pilot and the antenna of the planes that regularly use the runway. The distance is going to be equal to the medium length between the threshold and the beginning of the landing, adding a corrector factor due to the difference between the vertical length of the pilot eyes and the antenna. This factor can be obtained by multiplying the medium vertical distance between the pilot eyes and the antenna with the cotangent of the approximation angle.

Considering the landing distance of 400m and making use of the Annex 14, the factor of correction can be obtained considering a landing angle of 3°. The value obtained is 53,31m. Thus, the final PAPI location is 453,31m.

In order to state the perpendicular distance between the PAPI and the runway, the following picture taken from ICAO's manual determines that value.

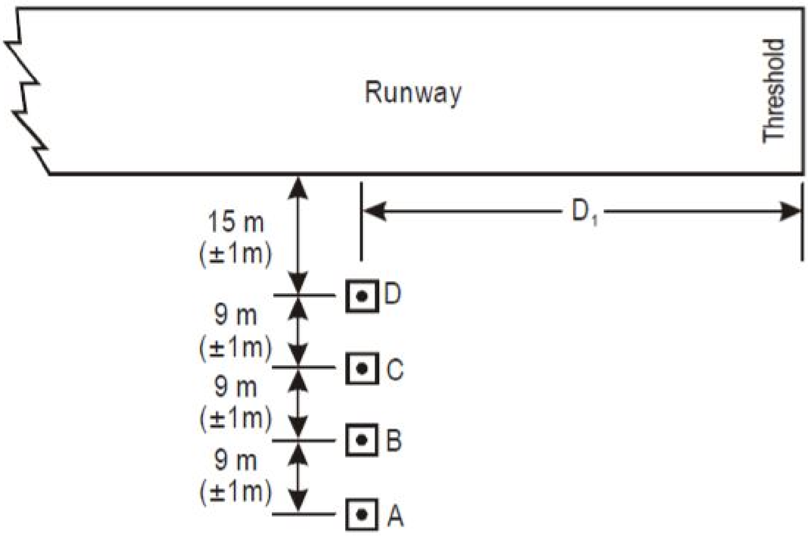

Figure 7.1.2: Vertical distance between the PAPI and the runway.

In order to ensure the visibility of the PAPI system, an area empty of obstacles must be defined. The parameters that define this protective surface are gathered in the following table extracted from the Annex 14, chapter 5:

	Runway type/code number							
	Non-instrument Code number				Instrument Code number			
Surface dimensions	1	2	3	4	1	2	3	4
Length of inner edge	60 m	80 m[a]	150 m	150 m	150 m	150 m	300 m	300 m
Distance from the visual approach slope indicator system[e]	D_1+30 m	D_1+60 m	D_1+60 m	D_1+60 m	D_1+60 m	D_1+60 m	D_1+60 m	D_1+60 m
Divergence (each side)	10%	10%	10%	10%	15%	15%	15%	15%
Total length	7 500 m	7 500 m[b]	15 000 m	15 000 m	7 500 m	7 500 m[b]	15 000 m	15 000 m
Slope								
a) T-VASIS and AT-VASIS	–[c]	1.9°	1.9°	1.9°	–	1.9°	1.9°	1.9°
b) PAPI[d]	–	A–0.57°	A–0.57°	A–0.57°	A–0.57°	A–0.57°	A–0.57°	A–0.57°
c) APAPI[d]	A–0.9°	A–0.9°	–	–	A–0.9°	A–0.9°	–	–

Figure 7.1.3: Dimensions and slopes of the obstacle protection surface.

The following figure extracted from the ICAO's manual can ease the understanding of the PAPI and its protection surface function:

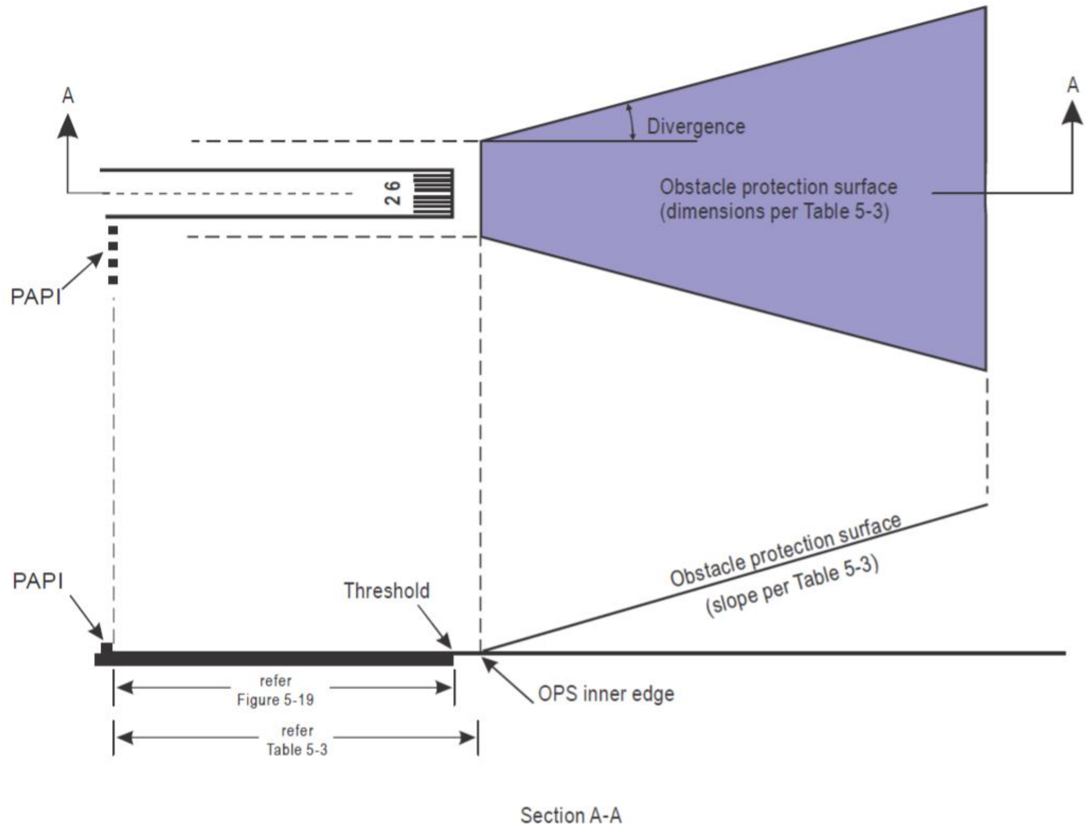

Figure 7.1.4: Protection surface scheme and PAPI positioning.

7.1.3 Runway threshold identification lights

The rules that regulate the runway threshold identification lights can be found on chapter 5.3.8 of the Annex 14. As a conclusion, the following statements define when should the threshold identification lights be included in the airport's installation:

- In a visual approximation runway, when there are no more other reliable visibility aids.

- The threshold is permanently or temporary displaced from the beginning of the runway.

Due to the fact that non of those requirements are meet, those lights have been discarded.

7.1.4 Runway edge lights

Unlike the last set of lights, the runway edge lights are a must since the airport is expected to work during night time too.

Runway edge lights shall be placed along the full length of the runway and shall be in two parallel rows equidistant from the centre line. Their distance from the edge should not exceed the 3m. Furthermore, The lights shall be uniformly spaced in rows at intervals of not more than 60 m for an instrument runway.

Runway edge lights shall be fixed lights showing variable white except 600m before the end of the runway, in this case, may show yellow.

7.1.5 Runway threshold and wing bar lights

Runway threshold will be provided since the runway is equipped with runway edge lights.

Location

The threshold lights shall be placed in a row at right angles to the runway axis as near to the extremity of the runway as possible and, in any case, not more than 3 m outside the extreme. Furthermore, due to our approximation category, the lights will be uniformly spaced between the rows of runway edge lights at intervals of not more than 3 m.

The use of wing bars is discarded since any of the runways is considered a visual approaching runway.

Characteristics

Runway threshold and wing bar lights shall be fixed unidirectional lights showing green in the direction of approach to the runway.

7.1.6 Runway end lights

Following ICAO's legislations, runway end lights shall be provided for a runway equipped with runway edge lights. Their location is on a line as close as possible to the end of the runway, in any case, not more than 3 m outside the end.

Characteristics

Runway end lights shall be fixed unidirectional lights showing red in the direction of the runway. The intensity and beam spread of the lights shall be adequate for the conditions of visibility and ambient light in which use of the runway is intended.

The final configuration adding the contribution of the end lights and the threshold lights is the following:

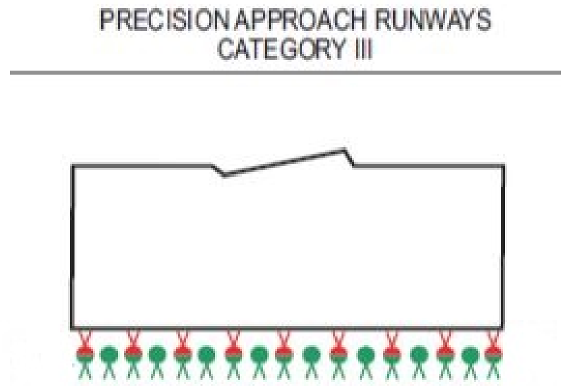

Figure 7.1.5: Scheme showing the lights placed on the edge of the runway.

7.1.7 Runway centre line lights

According to 5.3.12.11 the airports with precision approach runway of category II or III must provide centre line lights.

Location

Runway centre line lights shall be located along the centre line of the runway, except that the lights may be uniformly offset to the same side of the runway centre line by not more than 60cm. The lights shall be located from the threshold to the end at longitudinal spacing of approximately 15m.

Characteristics

Runway centre line lights shall be fixed lights showing variable white from the threshold to the point 900 m from the runway end; alternate red and variable white from 900 m to 300 m from the runway end; and red from 300 m to the runway end, except that for runways less than 1 800 m in length, the alternate red and variable white lights shall extend from the midpoint of the runway usable for landing to 300 m from the runway end.

7.1.8 Touchdown zone lights

Location

Touchdown zone lights shall extend from the threshold for a longitudinal distance of 900m and the longitudinal spacing between pairs of barrettes shall be either 30m or 60m.

Characteristics

A barrette shall be composed of at least three white unidirectional variable lights with a spacing between the lights of not more than 1,5m. Its length will be higher than 3 and lower than 4,5m in order to successfully follow the recommendation 5.3.13.4.

7.1.9 Rapid exit taxiway indicator lights

A set of rapid exit taxiway indicator lights shall be located on the runway on the same side of the runway centre line as the associated rapid exit taxiway. In each set, the lights shall be located 2 m apart and the light nearest to the runway centre line shall be displaced 2 m from the runway centre line. Furthermore, rapid exit taxiway indicator lights shall be fixed unidirectional yellow lights, aligned so as to be visible to the pilot of a landing aeroplane in the direction of approach to the runway.

The following scheme simplifies the explanation shown above and can also be used to give an example of the application of the rapid exit taxiway indicator lights:

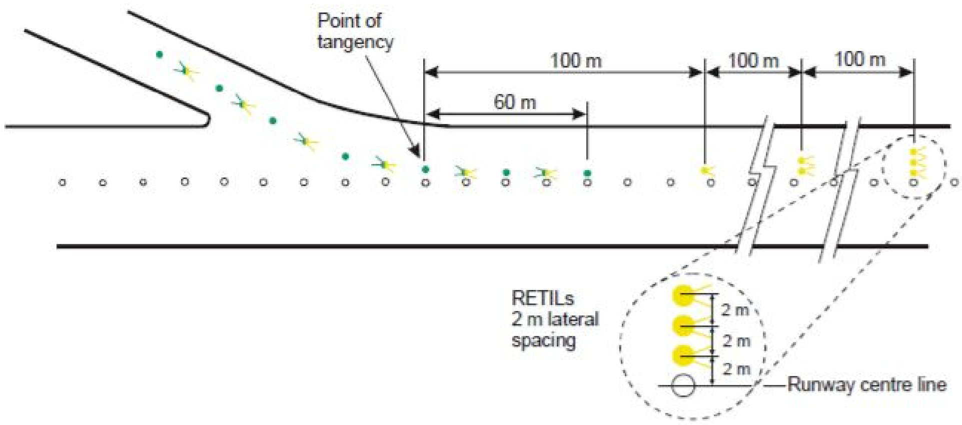

Figure 7.1.6: Example of rapid exit runway lights.

7.2 Taxiway lights

7.2.1 Taxiway lights

7.2.2 Taxiway lights for an exit taxiway

7.2.3 Taxiway light for a rapid exit taxiway

7.2.4 Taxiway edge lights

7.2.5 Stop bar lights

7.2.6 Intermediate holding point lights

7.3 Apron lights

7.3.1 Centre line and edge apron lights

Due to the fact that many taxiways light interfere with the apron area, such as the article 5.3.22 and the 5.3.17.1, the decision made is to configure the centre line and edge apron lights like in the runways.

7.3.2 Projector based apron lighting

Due to the fact that the apron is going to be used during night-time, the use of some high power illumination is a must. According to the point 5.3.24.3, the spectral distribution of apron floodlights shall be such that the colours used for aircraft marking connected with routine servicing, and for surface and obstacle marking, can be correctly identified.

Furthermore, even tough it is not a must, some other recommendations will be followed, such as an horizontal luminance of 20lux with a uniformity ratio of not more than 4 to 1; and a vertical luminance of 20lux at a height of 2m above the apron in relevant directions.

The lights installed on the terminal will follow the orientation shown in the picture below, as it can be seen, noon of them is directly pointing to any pilot.

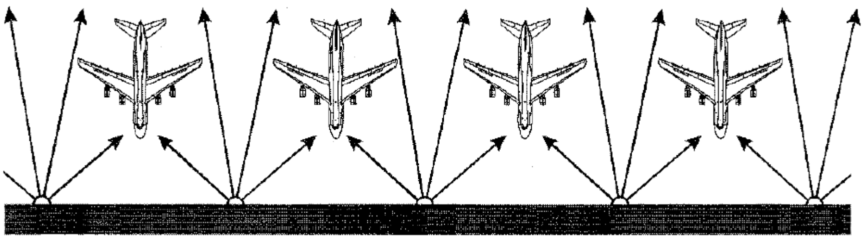

Figure 7.3.1: Terminal's fixed projectors and their orientation.

7.3.3 Visual guidance system for parking

Following the point stated in 5.3.25.1, a visual docking guidance system shall be provided when its intended to indicate, by a visual aid, the precise position of an aircraft stand.

Characteristics

According to ICAO, the azimuth guidance unit and the stopping position indicator shall be located in such a way that there is continuity of guidance between the aircraft stand markings, the aircraft stand manoeuvring guidance lights, if present, and the visual docking guidance system. Furthermore, the system should be able to be shut down by the pilot at any means and should indicate its malfunction in case of it.

In addition, the accuracy of the system should be adequate to the type of air plane and airport.

Azimuth Guidance Unit

Location

According to article 5.3.25.9, the azimuth guidance unit should be located on or close to the extension of the stand line ahead of the aircraft so that its signals are visible from the cockpit and aligned for use at least by the pilot occupying the left seat.

Characteristics

The azimuth guidance unit shall provide unambiguous left/right guidance which enables the pilot to acquire and maintain the lead-in line without over-controlling.

Furthermore, when azimuth guidance is indicated by colour change, green shall be used to identify the centre line and red for deviations from the centre line.

Stop position indicator

Location

The stopping position indicator shall be located in conjunction with, or sufficiently close to, the azimuth guidance unit so that a pilot can observe both the azimuth and stop signals without turning the head. Once more, the stop position indicator should at least be usable for the pilot occupying the left seat.

Characteristics

The stopping position indicator shall show the stopping position for the aircraft for which guidance is being provided and shall provide closing rate information to enable the pilot to gradually decelerate the aircraft to a full stop at the intended stopping position.

8 Signs

8.1 Introduction

Signs main objective is to give some information to the pilots about what lies ahead in order to guarantee the perfect organisation and efficiency of the aircraft trajectory while on taxiways.

The criteria used in order to dimension and calculate the position of each sign can be obtained from a table stated on the point 5.4 of the Annex 14.

Sign height (mm)				Perpendicular distance from defined taxiway pavement edge to near side of sign	Perpendicular distance from defined runway pavement edge to near side of sign
Code number	Legend	Face (min.)	Installed (max.)		
1 or 2	200	400	700	5–11 m	3–10 m
1 or 2	300	600	900	5–11 m	3–10 m
3 or 4	300	600	900	11–21 m	8–15 m
3 or 4	400	800	1 100	11–21 m	8–15 m

Figure 8.1.1: Location distances for taxiing guidance signs.

Since the airport designed has a number reference of 4, the distance from the runway to the sign will be 12m and the distance from the taxiways will be 15m. Two different values have been chosen in order to help the pilots differentiate which sign are they looking at.

Another important aspect to be taken into account is the fact that all the signs will have inside illumination in order to allow the night time operations.

8.2 Mandatory instruction signs

Application

A mandatory instruction sign shall be provided to identify a location beyond which an aircraft taxiing or vehicle shall not proceed unless authorized by the aerodrome control tower. The signs included in this section are: designation signs, category I, II or III holding position signs, runway-holding position signs, road-holding position signs and NO ENTRY signs.

Location

The location of each sign depend on the prohibition or the information they are giving:

- A runway designation sign at a taxiway/runway intersection or a runway/runway intersection shall be located on each side of the runway-holding position marking facing the direction of approach to the runway.

- A category I, II or III holding position sign shall be located on each side of the runway-holding position marking facing the direction of the approach to the critical area.

- A NO ENTRY sign shall be located at the beginning of the area to which entrance is prohibited on each side of the taxiway as viewed by the pilot.

Characteristics

A mandatory instruction sign shall consist of an inscription in white on a red background. Furthermore, in the specific case of inscription on a category I, II, III, joint II/III or joint I/II/III holding position sign shall consist of the runway designator, it must be followed by CAT I, CAT II, CAT III, CAT II/III or CAT I/II/III, as appropriate.

Examples

Now that the mandatory instruction signs have been fully explained and defined, the next step is to place those signs in the airport. Some examples of the sign placed will be shown and explained:

The NO ENTRY sing have been installed at the beginning of every rapid exit taxiway in both sides in order to aware the pilot that those taxiways are only allowed for the planes that land to exit the runway, entering the runway through a rapid exit way is strictly forbidden. The next figure shows the sign mentioned above:

Figure 8.2.1: No entry sign positioning and example.

The following sign is used in order to indicate the holding position and has to be placed in both sides of the runway that leads to that critical area:

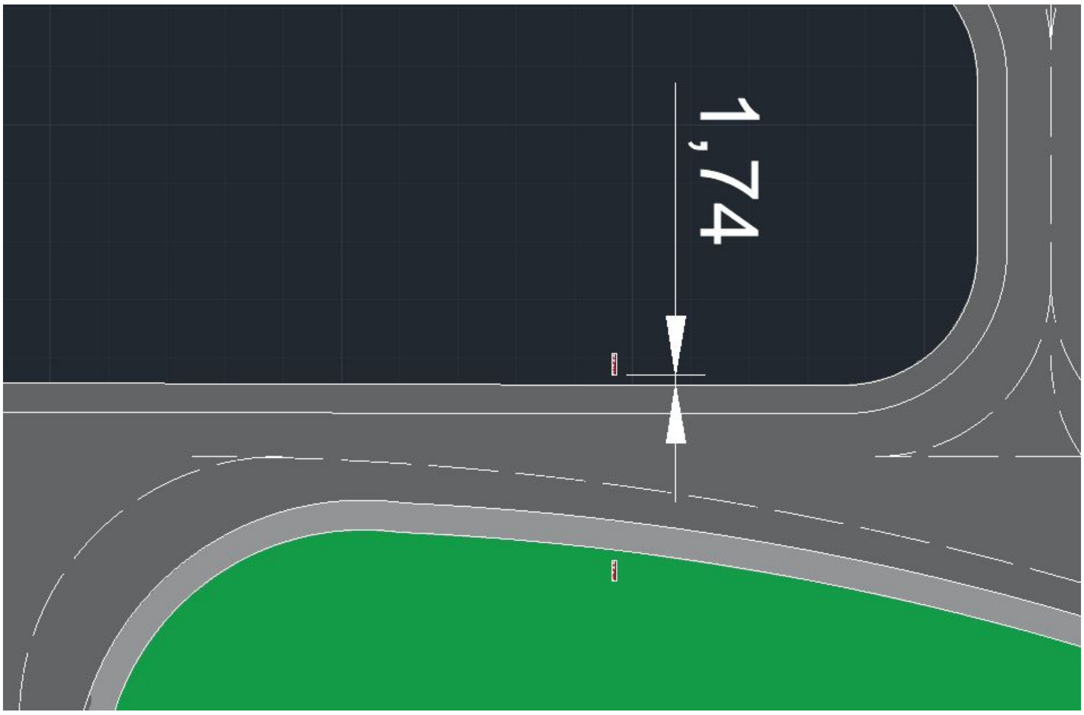

Figure 8.2.2: Holding positioning sign.

Since the sings can not be appreciated in the images due to the difference on the scale, some of the signs mentioned above will be shown in a bigger scale:

Figure 8.2.3: Examples of the mandatory instruction signs used in the airport.

As it can be seen, both runways have their holding position in the direction 19, thus they have to be differentiated by an R (right) or L (Left), depending on the runway. Furthermore, the sign also displays information about the runway category. The other sign shown in the figure is the no entry sign.

8.3 Information signs

Application

An information sign shall be provided where there is an operational need to identify by a sign, a specific location, or routing information. Furthermore, information signs shall include: direction signs, location signs, destination signs, runway exit signs, runway vacated signs and intersection take-off signs.

Location

Wherever practicable, the signs must be located on the left-hand side of the taxiway in accordance with table shown at the beginning of the section. Depending on the information sign, they get a different location:

-At a taxiway intersection, information signs shall be located prior to the intersection and in line with the intermediate holding position marking. Where there is no intermediate holding position marking, the signs shall be installed at least 60 m from the centre line of the intersecting taxiway where the code number is 3 or 4, and at least 40 m where the code number is 1 or 2.

- A runway exit sign shall be located prior to the runway exit point in line with a position at least 60 m prior to the point of tangency where the code number is 3 or 4, and at least 30 m where the code number is 1 or 2.

Characteristics

A location sign shall consist of an inscription in yellow on a black background and where it is a stand-alone sign shall have a yellow border and the inscription on a runway exit sign shall consist of the designator of the exit taxiway and an arrow indicating the direction to follow.

Examples

As for the mandatory instruction signs, now that the information signs have been defined, some examples will be given in order to ease the understanding of their function:

The first signs that will be exemplified will be the available runway length information signs. Those signs are placed in the entrance to the runway and give the available length that the aircraft has in order to perform the takeoff. Generally, they are only given in one side of the intersection.

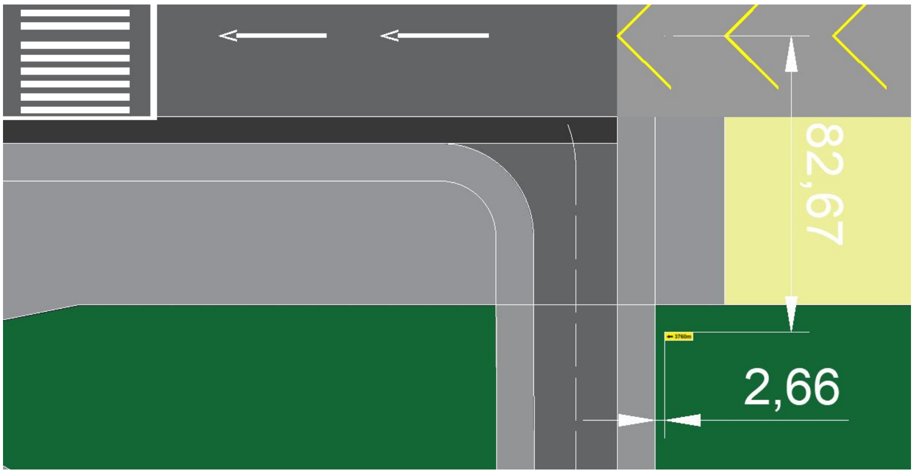

Figure 8.3.1: Available length information sign positioning.

The next signs that will also be explained are the ones that show information about the exit runway letter after landing. Each exit has assigned a different letter, thus there is one sign for each exit and rapid exit. All the signs will be place at the same distance from the runway.

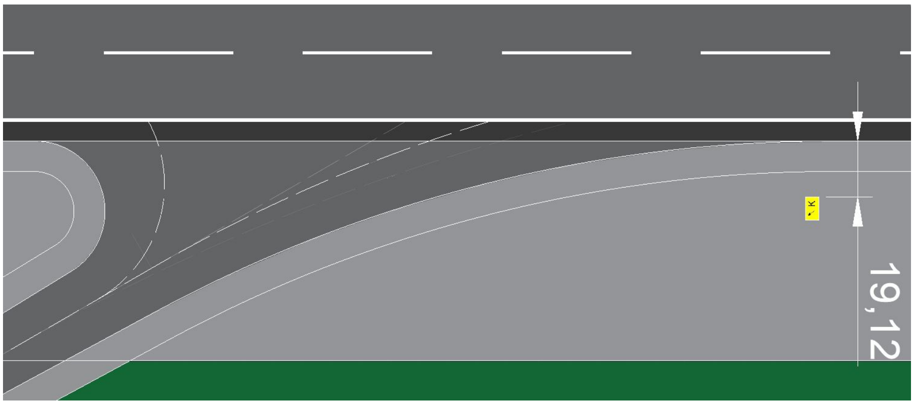

Figure 8.3.2: Exit runway sign distances and positioning.

Finally, an image with some of the informative sign will be shown:

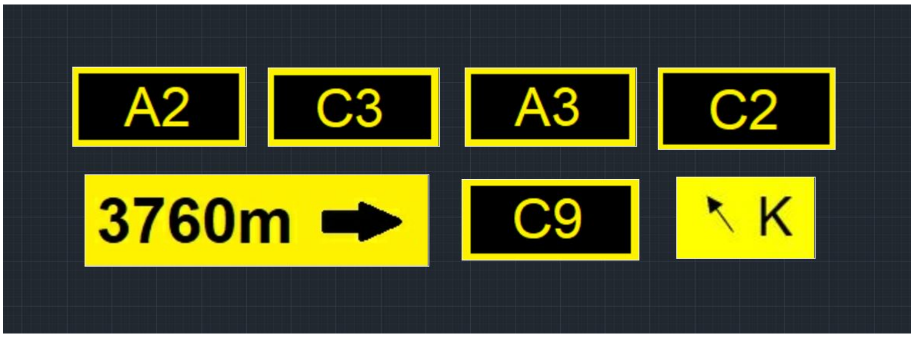

Figure 8.3.3: Exit runway sign distances and positioning.

The signs with black background and a yellow rectangle are the signs used in order to inform the pilot which is his current location.

9 | High-voltage electrical system

The design and provision of electrical power systems for aerodrome visual and radio navigation aids will be such that an equipment failure will not leave the pilot with inadequate visual and non-visual guidance or misleading information. Therefore, Electrical system will be designed following the regulations from [1], [2] and [3].

9.1 Electrical system general design

For the airport electrical system, two independent incoming power sources, coming from widely separated sections of the electricity network beyond the aerodrome, with each supplying separate substations on the aerodrome property will be used. Selection is, therefore, on the basis of least probability of simultaneous failure of both sources.

Power to the aerodrome main power substation will be supplied at a high voltage (over 110 000 volts). Then the voltage will be reduced on the aerodrome substation (Service Drop stations) to an intermediate voltage (25 000 volts) for distribution within the aerodrome. A further step-down of voltage will be necessary to match the required input voltage of visual aids equipment and terminal solicitations.

Aerodrome reliability will be improved by using a double loop system from independent primary sources operating as open rings fed from two transformers at each station.

The general electric system for the whole airport is detailed on figure 9.1.1.

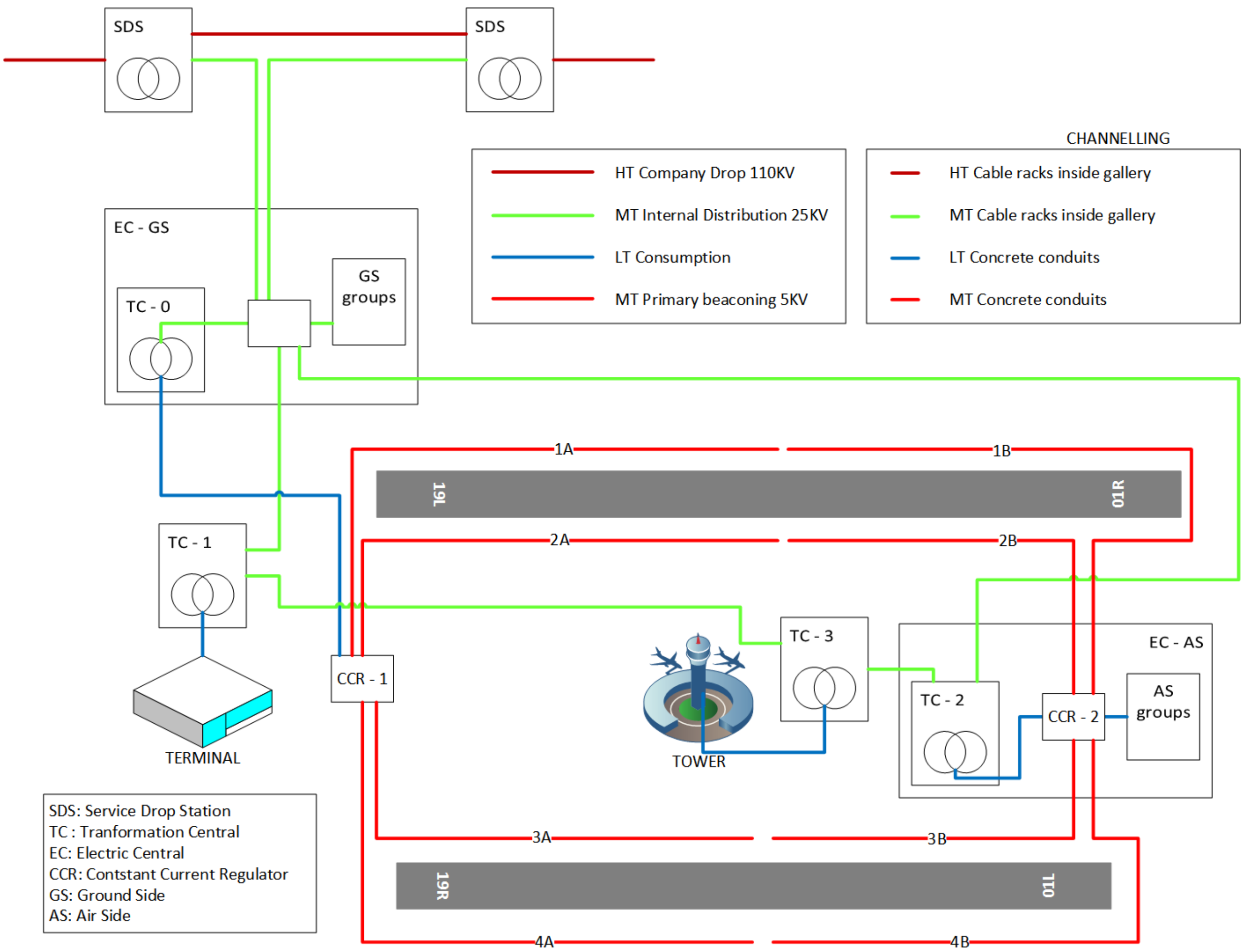

Figure 9.1.1: General electric system scheme

9.2 Connection sub-stations or Service Drop stations

Designated on figure 9.1.1 with SDS (Service Drop Stations), they are located on the top side of the figure. Electricity to the airport will be provided by two different suppliers in order to reduce the chance of the whole system failure.

As previously explained, High Voltage (HV) from the supplier network around 110kV will be drop into the airport network with this connection sub-stations. On figure 9.2.1, the wiring scheme can be seen: high voltage arrive to the substation making use of the HV towers on the left of the image, then the voltage is steeped-down to an internal distribution voltage level, Medium Voltage 25KV.

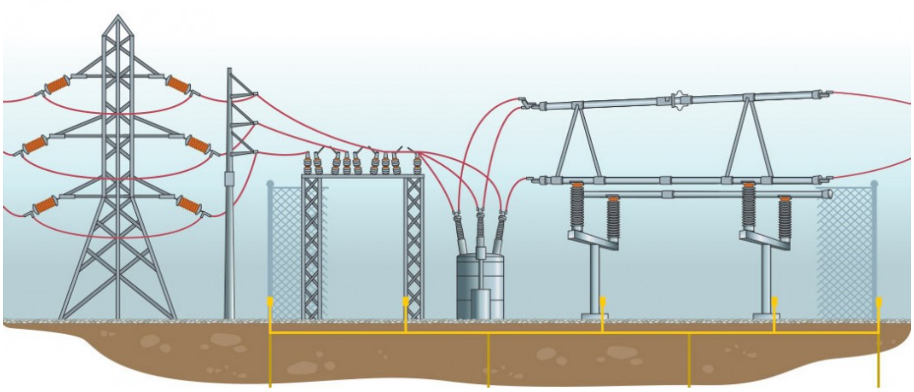

Figure 9.2.1: General electric system scheme

9.3 Electric power plant

The new airport will have two electric power plants, one for the ground side (EC - GS) and another for the air side (EC - AS). These power plants will work with medium tension values, 25KV. Ground side power plant will be in charge of feeding the terminal building and also the air side power plant. In addition, Air side power plant will supply electricity to all the beaconing circuit, visual aids, tower and aircraft control systems.

Both power plants have an electrical transformation centre to step-down the medium voltage to a Low voltage 380V. Sometimes, as seen on figure 9.3.1, power plants also incorporate a tension regulator centre.

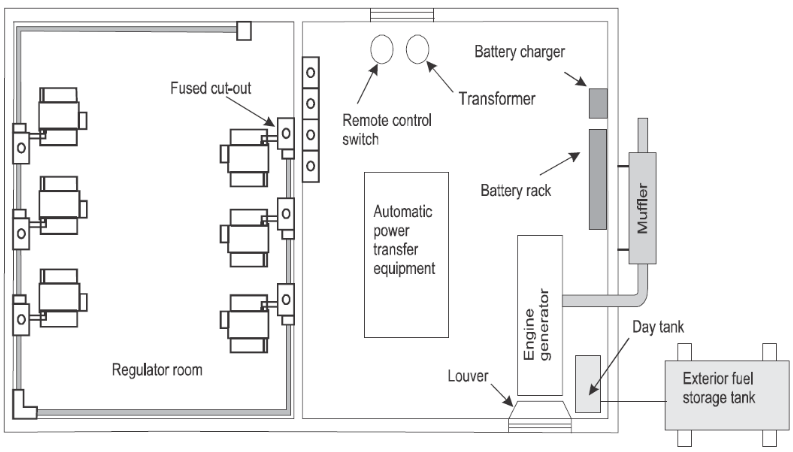

Figure 9.3.1: Power plant general scheme.

In case of the network suppliers electricity failure, power plants, have electricity generator power groups that able to carry on the electricity supply and act as a secondary power supply.

Air Side power plant, must be able to switch on the secondary power supply in a limited time according to the table 9.3.2. Theses circuits requirements will explained in the next sections.

Runway	*Lighting aids requiring power*	*Maximum switch over time*
Nonprecision approach	Approach lighting system Visual approach slope indicators (a) (d) Runway edge (d) Runway threshold (d) Runway end Obstacle (a)	15 seconds 15 seconds 15 seconds 15 seconds 15 seconds 15 seconds
Precision approach Category I	Approach lighting system Runway edge (d) Visual approach slope indicators (a) (d) Runway threshold (d) Runway end Essential taxiway (a) Obstacle (a)	15 seconds 15 seconds 15 seconds 15 seconds 15 seconds 15 seconds 15 seconds
Precision approach Category II/III	Inner 300 m of the approach lighting system Other parts of the approach lighting system Obstacle (a) Runway edge Runway threshold Runway end Runway centreline Runway touchdown zone All stop bars Essential taxiway	1 second 15 seconds 15 seconds 15 seconds 1 second 1 second 1 second 1 second 1 second 15 seconds
Runway meant for take-off in runway visual range conditions less than a value of 800 m	Runway edge Runway end Runway centre line All stop bars Essential taxiway (a) Obstacle (a)	15 seconds (c) 1 second 1 second 1 second 15 seconds 15 seconds

(a) Supplied with secondary power when their operation is essential to the safety of flight operation.
(c) One second where no runway centre line lights are provided.
(d) One second where approaches are over hazardous or precipitous terrain.

Figure 9.3.2: Secondary power supply requirements for visual aids.

9.4 Electrical transformation centre

As its name suggest, these devices transform the electricity voltage level. In Bekasi new airport, transformation centres will step-down the medium voltage level 25KV to a Low voltage level for consumption 380V.

Airport will have four transforming centres: two for the beaconing circuits, one for the terminal building and the last one for the tower.

9.5 Channelling and distribution of the electrical system

Duct-line routes will be selected to balance maximum flexibility with minimum cost and to avoid foundations for future buildings and other structures. Where it may be necessary to run communication lines along with electric power distribution lines, two isolated systems in separate manhole compartments will be provided. Where possible, ducts should be installed in the same concrete envelope.

High Voltage and internal distribution medium tension electric circuit will be transported on metallic cable racks inside underground galleries, accessible by manholes on the surface like figure 9.5.1.

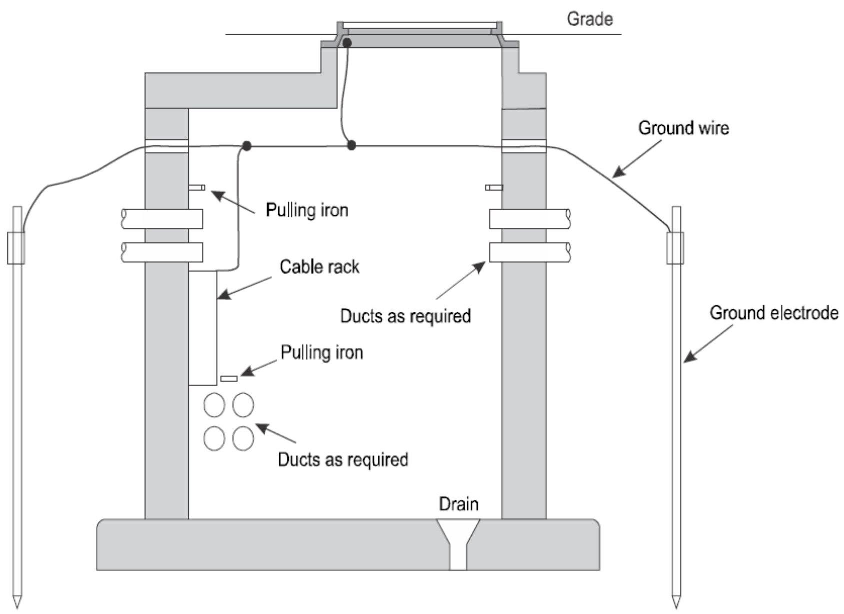

Figure 9.5.1: General manhole access to gallery distribution.

Note that these galleries will offer the possibility to allocate additional circuits and encased ducts.

10 | Medium voltage electrical system

10.1 Beacon circuits

In series circuit is selected for beacon circuits, illustrated in figure 10.1.1. This option is chosen because its advantages.

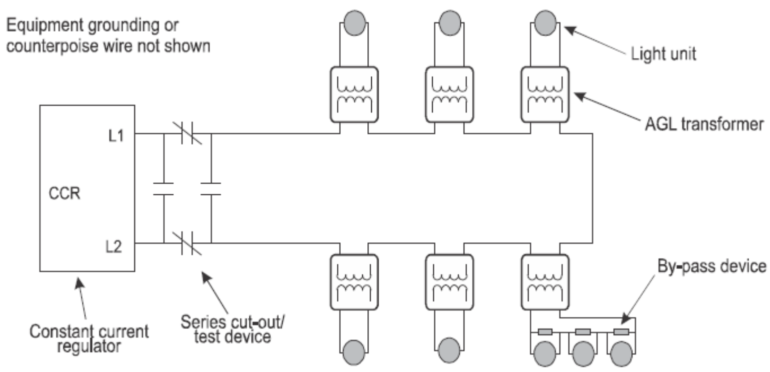

Figure 10.1.1: Series lighting circuit.

The constant current regulators of a series circuit, maintain a constant current independent of the load on the circuit. Thus, the same current will flow in a long circuit as in a shorter circuit and will remain the same even if some of the lamps fail. A short circuit across the output of a constant current regulator is a no-load condition and an open circuit is an overload. In a simple direct-connected series circuit, a lamp failure causes an open circuit; hence, it is necessary to provide an aerodrome ground lighting (AGL) transformer, as part of the circuit design, to maintain continuity of the circuit with lamp failure. Where a single transformer is used to supply several light units, as shown in Figure 10.1.1, a by-pass device is incorporated to ensure continuity on the secondary side.

10.1.1 Interleaving

As a further means of assuring availability in case of failure, arrangement is made to enable switching to a spare regulator, as shown in Figure 10.1.2. This method may be used where the regulator consists of the regulating component and input/output transformers. In the case of regulators that consist of only the regulating component, a rack mounted or plug-in design is used and availability is achieved by use of a spare regulator, Figure 10.1.3, that can be readily installed in place of the failed regulator.

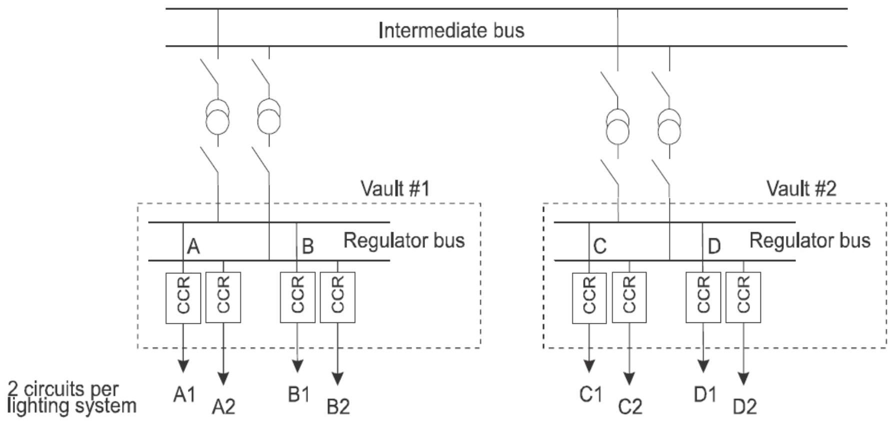

Figure 10.1.2: Provision of interleaved circuits.

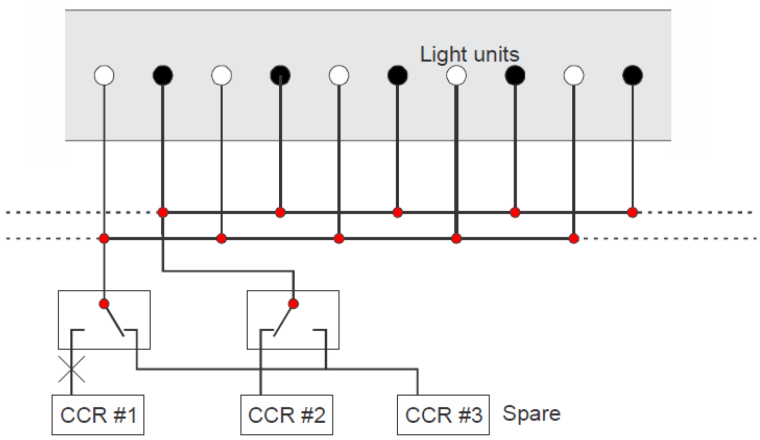

Figure 10.1.3: Use of a spare regulator.

10.1.2 Runway centreline and touchdown lighting systems

Annex 14, Volume I, requires that runway centreline lights show variable white to a distance of 900 m from the threshold, then alternating variable white and red from 900 m (or from the mid-point of the runway) to 300 m from the runway end after which only red is shown to the pilot. Figure 10.1.4 illustrates the interleaving for the first white only portion of the system. Similar interleaving would be used for the final all red portion.

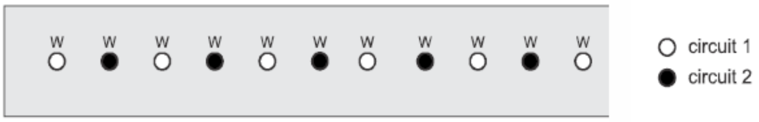

Figure 10.1.4: Runway centreline.

Interleaving to preserve spacing, Figure 10.1.5, is selected for the coded white/red portion of the system. This configuration, does not preserve the coding (with circuit failure the lights are either all red or all white), but does maintain an acceptable spacing for provision of a pattern of lights for centreline guidance (the spacing is doubled with circuit failure).

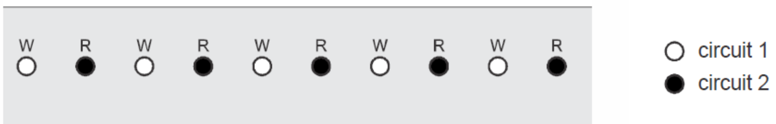

Figure 10.1.5: Interleaving to preserve spacing.

Figure 10.1.6 also illustrates the interleaving of runway touchdown zone lights. In this case three circuits will be used to preserve longitudinal spacing in case of one circuit failure.

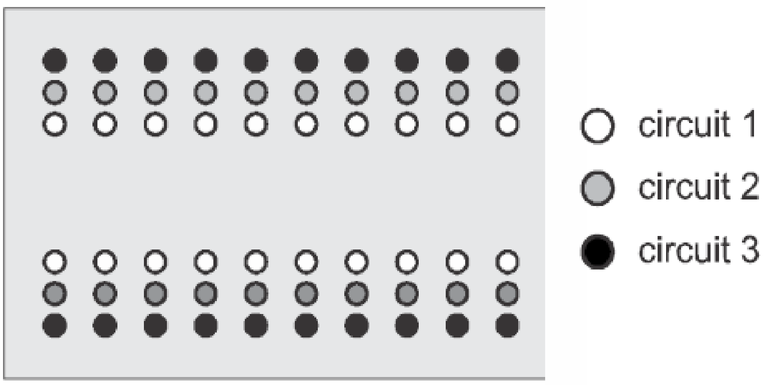

Figure 10.1.6: Interleaving by horizontal lines with three circuits.

10.1.3 Taxiway centreline lighting system

Taxiway centreline lighting circuits will be interleaved on those parts of the taxiway system that are considered as essential in category II/III conditions but, for economic reasons, a single circuit may be used for other taxiways.

Three circuits for interleaving procedure will be use, figure 10.1.7. Because there is a lot of operations movement, is essential to preserve both spacing and colour, to reduce the chance of pilots getting lost.

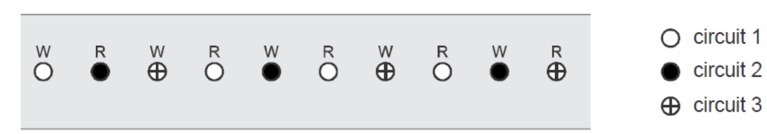

Figure 10.1.7: Interleaving to preserve both spacing and colour.

10.1.4 Stop bar electrical circuit

Stop bars will be controlled independently of each other and of the taxiway centreline lights. The electrical circuits will be interleaved so that all of the lights of a stop bar will not fail at the same time.

10.1.5 Approach lighting system

10.1.5.1 Visual approach, PAPI electrical circuit

Visual approach slope indicator systems will have two circuits per runway end because they are operated with an ILS system.

A full PAPI or T-VASI will be installed on both sides of the runway, the power to all light units on one side of the runway will be supplied by the same circuit. This arrangement ensures that should one circuit fail a complete pattern will be retained on the other side of the runway.

10.1.5.2 Precision approach

Precision approach interleaving implemented are summarized on figure 10.1.8.

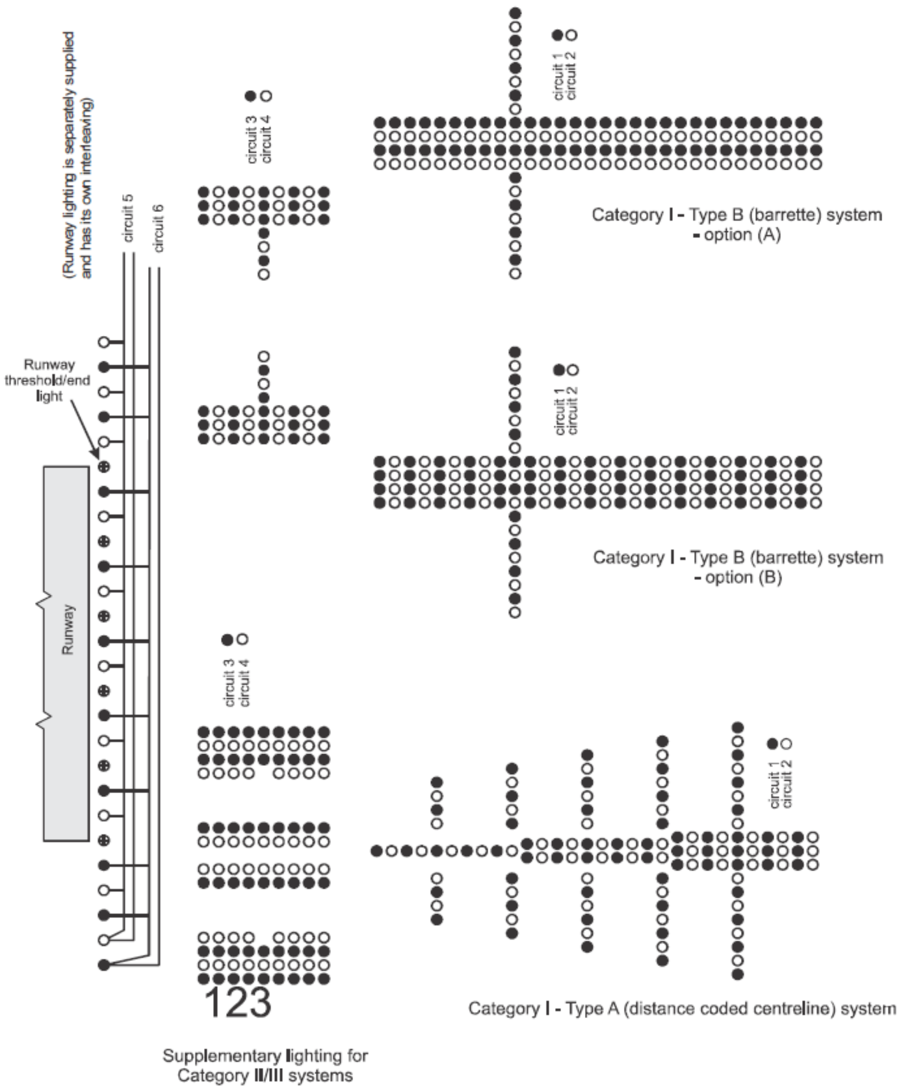

Figure 10.1.8: Precision approach lighting system interleaving.

10.1.6 Runway holding position signs

Runway holding position signs will be installed such that separate circuits are used for the signs on each side of the taxiway.

10.1.7 RETIL electrical circuit

The rapid exit taxiway indicator lights (RETIL) system is composed of a pattern of in-pavement fixtures used to indicate the approach to a runway exit. In as much as the system has a small quantity of fixtures and each is necessary for the distance coding, the

RETIL system is not provided with interleaving but has a single circuit that is fed from a separate constant current regulator.

Failure of one light within a barrette results in a malfunction of the system. Therefore, the system will be provided with an automatically turn off the entire system circuit, if there is a loss of a single light unit.

10.2 Constant current regulators

The electrical power for the aerodrome ground lighting circuits (series circuit) is supplied by constant current regulators (CCRs) because this facilitates constant light output over long distances, as is the case for aerodrome runways. The regulators are designed to produce a constant current output that is independent of variations in the circuit load and input voltage of the power source. They are also designed to provide two or more output currents when dimming of the lights is required.

Projected airport will have two CCRs in order to power the aerodrome ground lighting circuit. Each one, powers the lights of half of each runway.

10.3 Wire channelling

Primary beaconing 5KV grid and low tension circuit will be installed in ducts encased in concrete, figure 10.3.1. All ducts installed in concrete encasement will be placed on a layer of concrete not less than 75 mm thick.

Flared ends of ducts or couplings will be installed flush with the concrete encasement or inside walls of manholes or handholes. Interlock spacers will be used at not more than 1.5 m spacing to ensure uniform spacing between ducts. Joints in adjacent ducts will be staggered a minimum of 600 mm apart and will be made waterproof prior to concreting. Concrete-encased duct will be installed so that the top of the concrete envelope or conduit is not less than 450 mm below the stabilized base course where it is installed under roadways, railroads, runways, taxiways, other paved areas and ditches, and not less than 450 mm below the finished grade elsewhere. Counterpoise wires are provided as required.

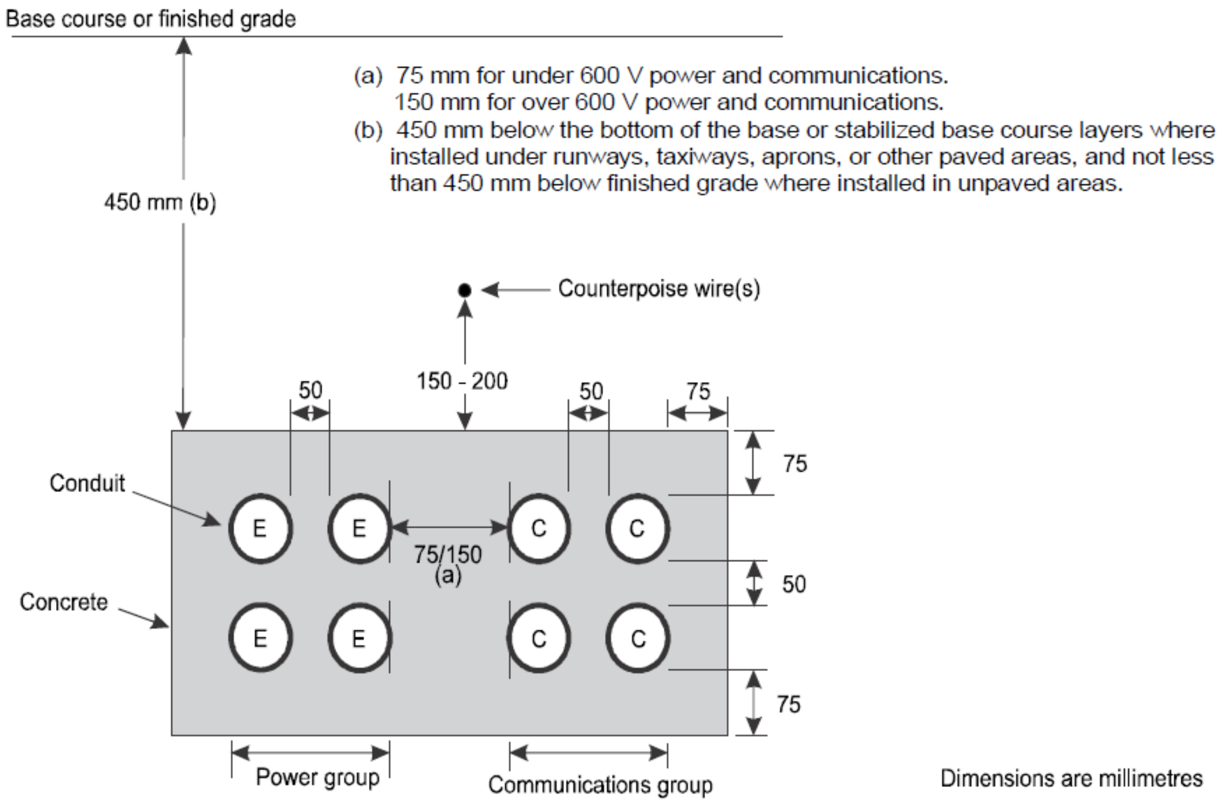

Figure 10.3.1: Concrete encased duct bank.

In order to make easier the maintenance and installation, these connections will be simple and when possible in straight lines. When there is a change in direction, a manhole or hand-hole will be installed.

11 | Aeronautical limitation surfaces

11.1 Physical limitation surfaces

As runaway 1 and 2 are both classified as category 4, the dimensions of the Aeronautical Servitudes are the same for both. Using the defined OBSTACLE LIMITATION SURFACES (figure 11.1.1), on ATTACHMENT B of [3].

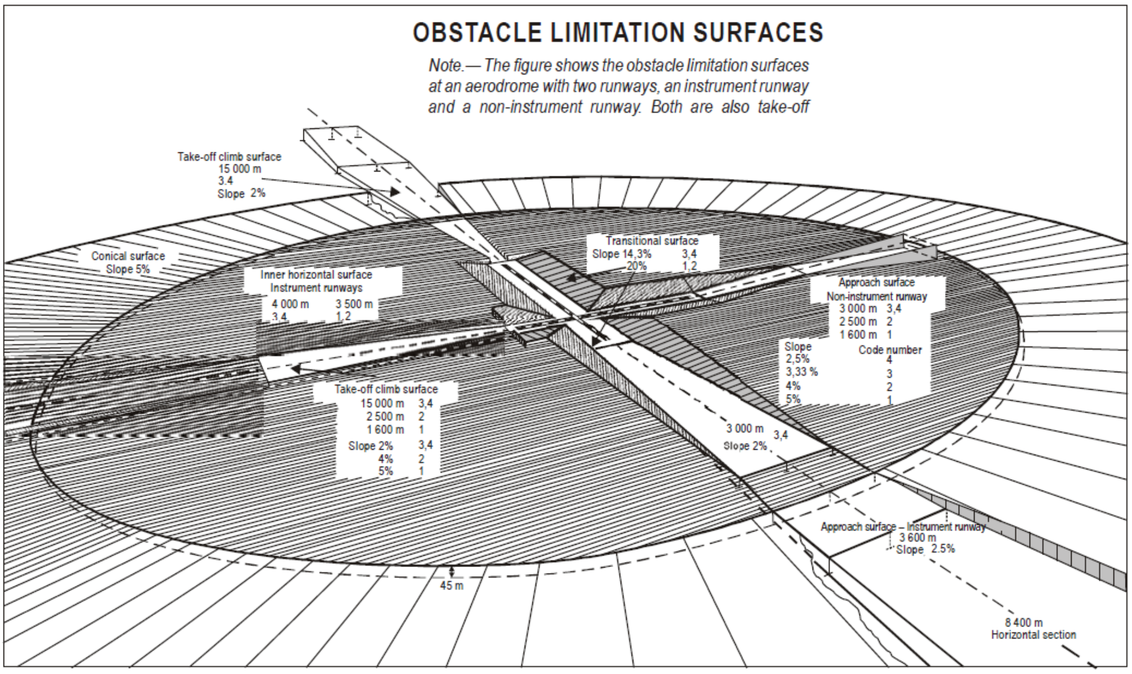

Figure 11.1.1: Obstacle Limitation Surface model.

The servitudes for each runway are determined on the following table and represented on figure 11.1.2.

RUNWAYS 1 & 2

Conic	
Slope	5%
Height	100m
Internal Horizontal	
Height	45m
Radius	4.000m
Internal Approximation	
Width	120m
Distance from edge	60m
Length	900m
Slope	2%
Approximation	
Inner band length	300m
Distance from edge	60m
Divergence	15%
First section	
Length	3.000m
Slope	2%
Second section	
Length	3.600m
Slope	2.5%
Horizontal section	
Length	8.400m
Total length	15.000m
Transition	
Slope & 14.3%	
Inner Transition	
Slope	33.3%

Interrupted Landing	
Inner band length	120m
Distance from edge	1800m
Divergence	10%
Slope	3.3%
Take-off Climb	
Inner band length	180m
Distance from edge	60m
Divergence	12.50%
Final width	1.200m
Length	15.000m
Slope	2% (a)

Table 11.1.1: Runways 1 & 2 servitudes. (a): It is recommended to limit the presence of new objects to a surface with a slope of 1.6%

The obstacle free surfaces are the same for the two runways, since they are both of category III. All the data in the table is required in order to achieve this category of precision approximation.

After study of the terrain, it is concluded that there are no obstacles in inside the surfaces. The control tower is below the conic surface as well.

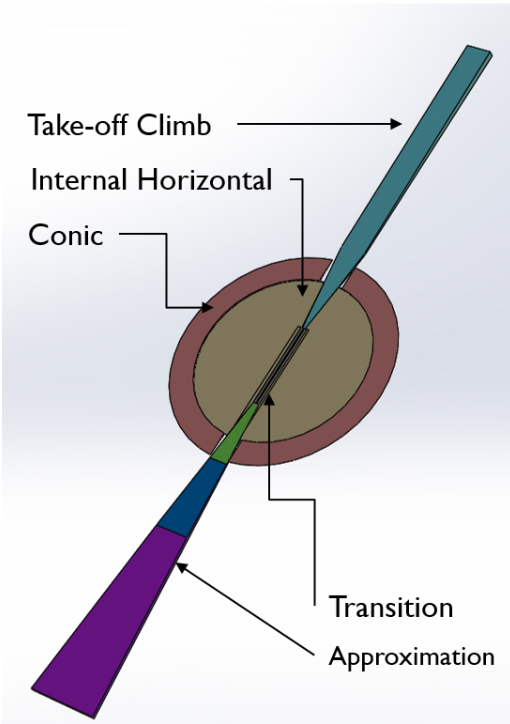

Figure 11.1.2: Servitudes 3D view.

11.2 ILS limitation surfaces

11.3 Localizer limitation surfaces

11.4 Gliding trajectory protection limitation surfaces

12 | Bibliography

[1] ICAO, *Doc 9157 - Aerodrome Design Manual Part 5: Electrical Systems*, 2006.

[2] M. D. E. Sanidad and T. Social, "BOE-A-2012-5403," 2009.

[3] I. Standards, R. Practices, I. C. Aviation, and A. Design, "Aerodromes," vol. I, no. July, 2016.